UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
GEORGIA POWER COMPANY, *et al.*	)	Docket Nos. 50-424 (OL)
	)	50-425 (OL)
(Vogtle Electric Generating Plant, Units 1 and 2)	)	

AFFIDAVIT OF THOMAS W. CROSBY,
CLIFFORD R. FARRELL, AND L. R. WEST

County of San Francisco)
) ss.
State of California)

Thomas W. Crosby, Clifford R. Farrell, and L. R. West, being duly sworn according to law, depose and say as follows:

1. Each of us is employed by Bechtel Civil and Minerals, Inc. Our business address is Bechtel Civil and Minerals, Inc., P. O. Box 3695, San Francisco, California 94119. Summaries of our professional qualifications and experience are attached hereto as Exhibits A, B, and C, which are incorporated herein by reference.

2. The purpose of this affidavit is to support Applicants' Motion for Summary Disposition of Joint Intervenors' Contention 7. The affidavit describes the geology and

hydrology at Plant Vogtle (VEGP) and the consequence of an accidental release of radioactive liquid to the ground-water. The affidavit also addresses specific allegations which the Joint Intervenors have made. We have personal knowledge of the matters set forth herein and believe them to be true and correct.

I. VEGP Geology and Hydrology

3. Plant Vogtle is located approximately 26 miles south-southwest of Augusta, Georgia, on the Coastal Plain of Georgia. See Figure 1. The plain is underlain by a sequence of sedimentary formations which have been deposited periodically beginning in late Cretaceous period (approximately 90 million years ago) and continuing to the present. The deposition is the result of repeated advance and recession of the Atlantic Ocean. This process has created a thick wedge of alternating and interfingering beds of sand, clay, marl, and limestone sediments atop a basement complex of older sedimentary, crystalline, and metamorphic rocks. The formations dip southeast, toward the Atlantic Ocean, at an angle slightly greater than the regional slope, as shown in Figure 2.

4. Some of the geologic units underlying the coastal plain have relatively high permeability (used synonomously with hydraulic conductivity in this affidavit) and constitute aquifers -- saturated permeable geologic units that can transmit significant quantities of water under ordinary hydraulic

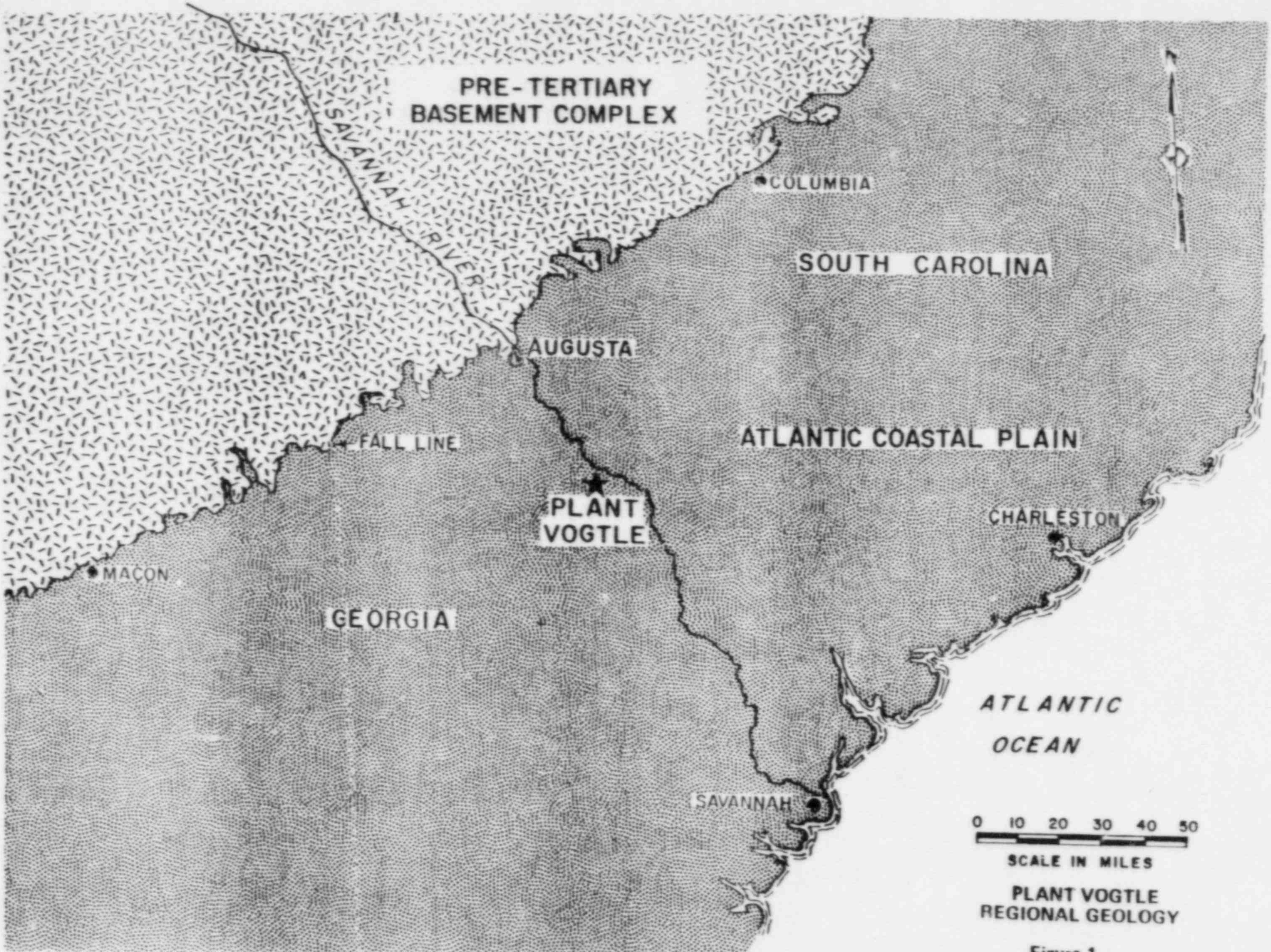

PRE-TERTIARY
BASEMENT COMPLEX
SAVANNAH RIVER
COLUMBIA
SOUTH CAROLINA
AUGUSTA
FALL LINE
ATLANTIC COASTAL PLAIN
PLANT
VOGTLE
CHARLESTON
MACON
GEORGIA
ATLANTIC
OCEAN
SAVANNAH
0 10 20 30 40 50
SCALE IN MILES
PLANT VOGTLE
REGIONAL GEOLOGY

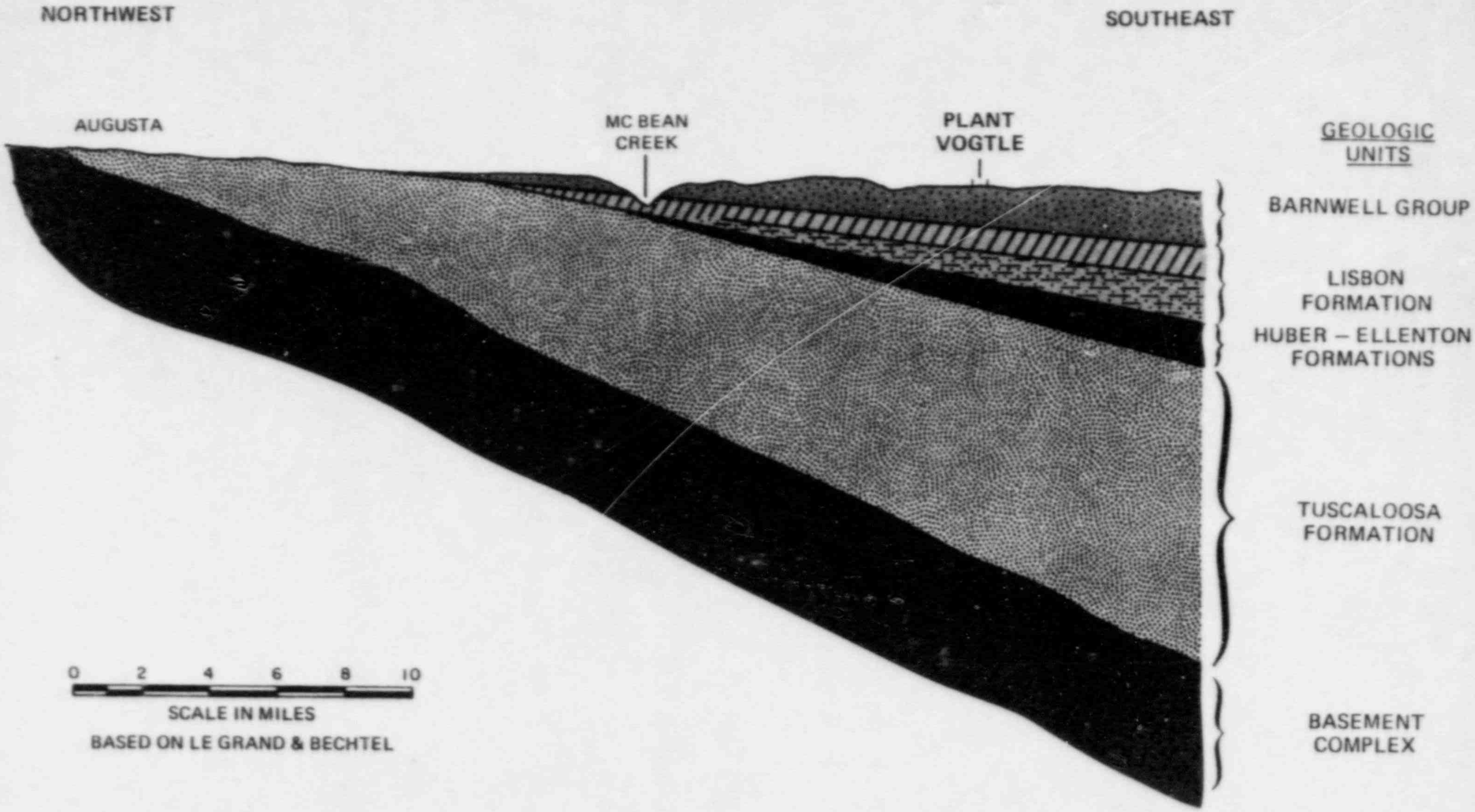
Figure 1

gradients. Other units have very low permeability and are classified as aquicludes, or confining beds -- saturated geologic units that transmit negligible amounts of water. When an aquifer is completely filled with water and is overlain by an aquiclude, it is classified as a confined (or artesian) aquifer.

5. The relationship of geologic units, aquifers, and the names assigned them are sometimes confused, primarily because of two factors. The most important factor is that the relationship between hydrologic and geologic units changes from one area to another; a geologic unit can be an "aquifer" in one area and an "aquiclude" in another. The second factor is that, unfortunately, each study or report for a specific area may assign its own names to each aquifer and geologic unit; when several studies are then compared, several names for the same unit may result. To allay this potential for confusion, the geologic units and aquifers beneath Plant Vogtle are identified and described below.

A. Geologic Units

6. The Tuscaloosa Formation overlies the basement complex. This formation consists primarily of sands and gravels with scattered beds of silt and clay. The Tuscaloosa sediments were deposited in late Cretaceous time, or about 90 million years ago. As shown diagramatically in Figure 2, the Tuscaloosa sediments are exposed at the surface near Augusta.



REGIONAL GEOLOGIC SECTION
PLANT VOGTLE

Figure 2

7. The Huber and Ellenton Formations were deposited on the Tuscaloosa sediments during the early Tertiary Period. These sediments consist of sandy clays and silts of dark gray and multicolored clays.

8. The Lisbon Formation was deposited atop the Huber and Ellenton during the Middle Tertiary Period. Beneath Plant Vogtle, the Lisbon Formation is comprised of a lower calcareous sand unit and an upper calcareous clay or marl. The lower sands do not have a formal name and are therefore called the unnamed sands. The calcareous clay marl has been named the Blue Bluff marl.

9. The Barnwell Group of sediments were deposited over the Lisbon Formation in the Late Eocene Epoch. The Barnwell Group is comprised of sand with minor amounts of clay and limestones. The Utley Limestone, which is the lowest strata in the group and which is not present everywhere, was locally deposited on the Blue Bluff marl. The overlying sediments of the Barnwell Group are composed primarily of sands and silts, and are exposed at the surface in the Plant Vogtle area.

10. The Hawthorn Formation sediments were deposited over the Barnwell Group sediments in the early Miocene Epoch (25 to 23 million years ago). The Hawthorn is the youngest Tertiary Formation in the vicinity of the plant site. These sediments consist of multicolored clayey sands and gravels.

B. Hydrogeologic Units

11. There are two major aquifers recognized in the coastal plain region, both of which are present beneath VEGP. The lower aquifer is called the Cretaceous aquifer and consists primarily of the sands and gravels of the Tuscaloosa Formation. It is often referred to as the Tuscaloosa aquifer.

12. The upper aquifer in the coastal plain region is called the Tertiary aquifer and consists primarily of permeable sands and limestones of several Tertiary-age geologic formations. This aquifer is also referred to as the principal artesian aquifer, or as the limestone aquifer in different parts of the Coastal Plain. At Plant Vogtle, the Tertiary aquifer is represented by the "unnamed sands" member of the Lisbon Formation. Beneath the Plant Vogtle area, these aquifers are confined. The uppermost confining layer is the Blue Bluff marl of the Lisbon Formation.

13. In addition to that contained in the Cretaceous and Tertiary aquifers, ground-water in the vicinity of VEGP also exists under water-table (unconfined) conditions in shallow and discontinuous, younger formations of the Barnwell Group. These discontinuous ground-water units are referred to as the water-table aquifer.

C. Methods of Investigation

14. Applicants have conducted extensive investigations of the geology and hydrology at and in the vicinity of the plant. These studies are up to date and demonstrate the suitability of the site for a nuclear power plant.

15. The investigations commenced with site exploration in 1971. A thorough search of the literature, stereoscopic examination of color air photographs, detailed evaluation of geologic conditions at and within five miles of the site, and geologic reconnaissance along 12 miles of the Savannah River bluff upstream and downstream were conducted. Field investigations involved geologic mapping, drilling, geophysical surveys, and ground-water studies. During this phase, 474 exploratory holes were drilled for a total of 60,000 feet of hole. The drilling program included electric logging, natural gamma, density, neutron, caliper, and three dimensional velocity logs in selected drill holes. Menard pressure meter tests were performed to determine in-situ engineering properties of the marl stratum, which is the load bearing unit for plant structures. The geophysical surveys consisted of a total of 28,400 feet of shallow refraction seismic lines, 5,000 feet of deep refraction lines, and cross-hole velocity measurements in the upper 290 feet of materials. (The results of these investigations are presented in Section 2.5 of the PSAR.)

16. Also during initial site exploration, well canvasses were conducted. A total of 280 wells were located and

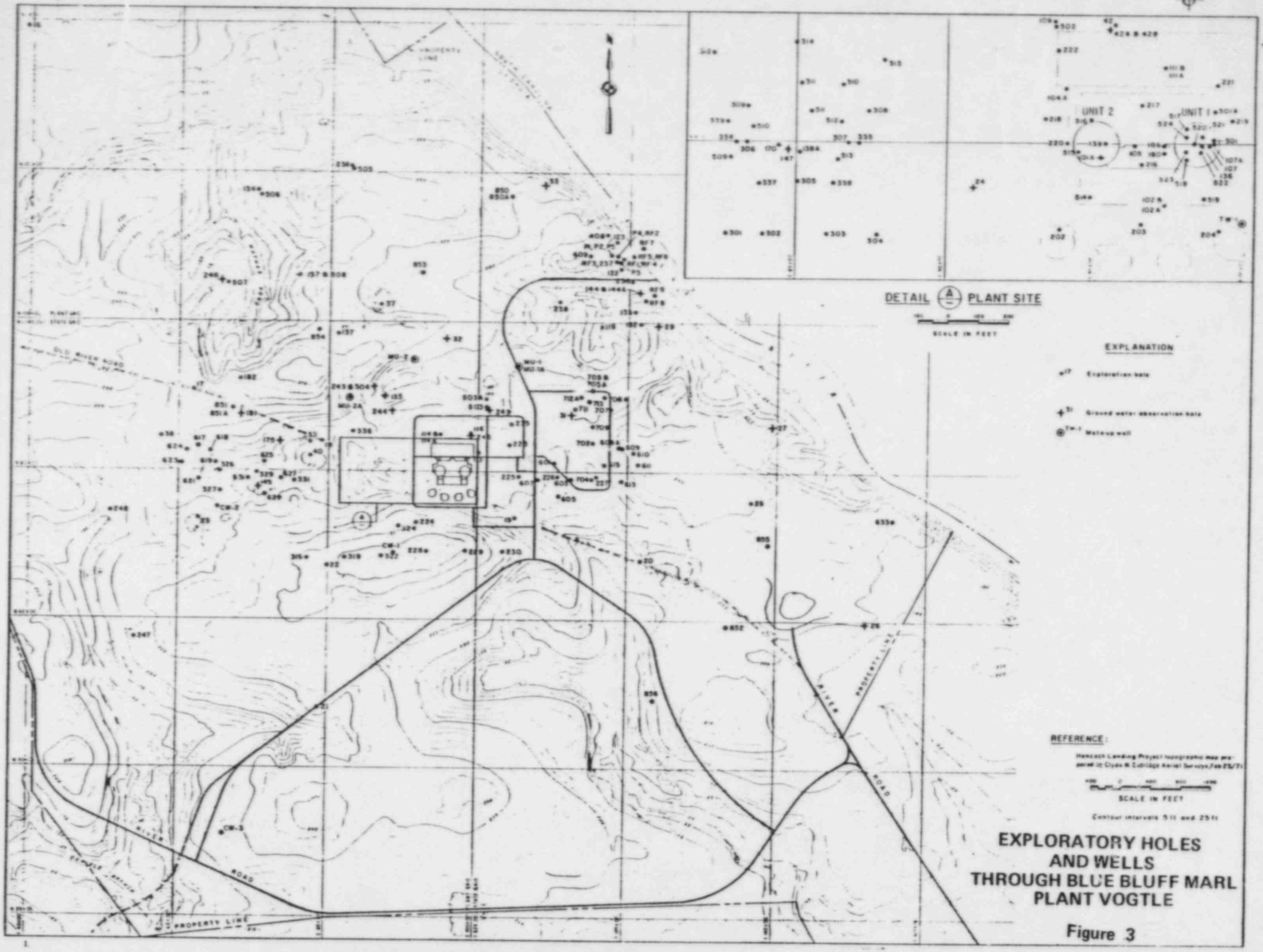
inspected on the west side of the Savannah River. These included all wells in use within 7 miles of the site, and sixty percent of the wells beyond to a distance of 10 miles of the site. (The data from these surveys is found in PSAR Table 2.4-4.)

17. Investigations of the geology and hydrology at VEGP continued during site excavation and construction. These included detailed geologic mapping of the soil and rock strata exposed during the power block excavation, and coring and testing of the Blue Bluff marl. Over 100 additional exploratory holes were drilled in the vicinity of Plant Vogtle. In addition, since initial site exploration in 1971, over 30 observation wells have been used to monitor water levels in the water-table aquifer; and the Tertiary aquifer has been monitored by 24 wells. Data has also been obtained from five wells open to Cretaceous aquifer. (Not all of these wells have been operational throughout the entire period of site exploration and construction; some wells have had to be abandoned and grouted due to their location near plant facilities.)

18. In May and June of 1982, another major well canvass was conducted to accumulate a comprehensive hydrogeologic data base to evaluate the postulated Millett fault. A total of 886 wells encompassing an area of approximately 4,400 square miles surrounding the plant were investigated. Geophysical well log data from both the State of Georgia Geological Survey and the U.S. Geological Survey were obtained and analyzed. As part of

the Millett study, 12 observation wells were installed along two lines southeast of the plant. The wells were drilled through the marl and monitored water levels in the Tertiary and Cretaceous aquifers below the marl. The data from these and other core holes provided accurate definition of the depth of geologic units, lithology, and aquifers from the plant to nineteen miles southeast of the plant, and evidenced the lateral extent of the marl. (The results of this study are found in "Studies of Postulated Millett Fault" October, 1982.) Even more recently, a 1984 well canvass was conducted to identify all offsite wells within a two-mile radius of the plant. (Results of this well canvass are presented in the FSAR at page Q240.5-1.)

19. This program of geologic mapping, drilling, geophysical logging, well monitoring, and permeability testing has reliably determined the location and characteristics of the geologic and hydrogeologic units in the vicinity of Plant Vogtle. In particular, exploratory drilling, which is the primary method for determining the geologic units and aquifers at a site, has provided extensive information on the depth, character, and areal extent of the subsurface units and aquifers. At Plant Vogtle, over 600 holes have been drilled. Over 200 of these explored the marl and provided a reliable data base on its characteristics. The locations of these holes are shown in Figure 3. Detailed geologic sections have been constructed from these data and are presented in FSAR Figures 2.5.1-14 through 2.5.1-21.



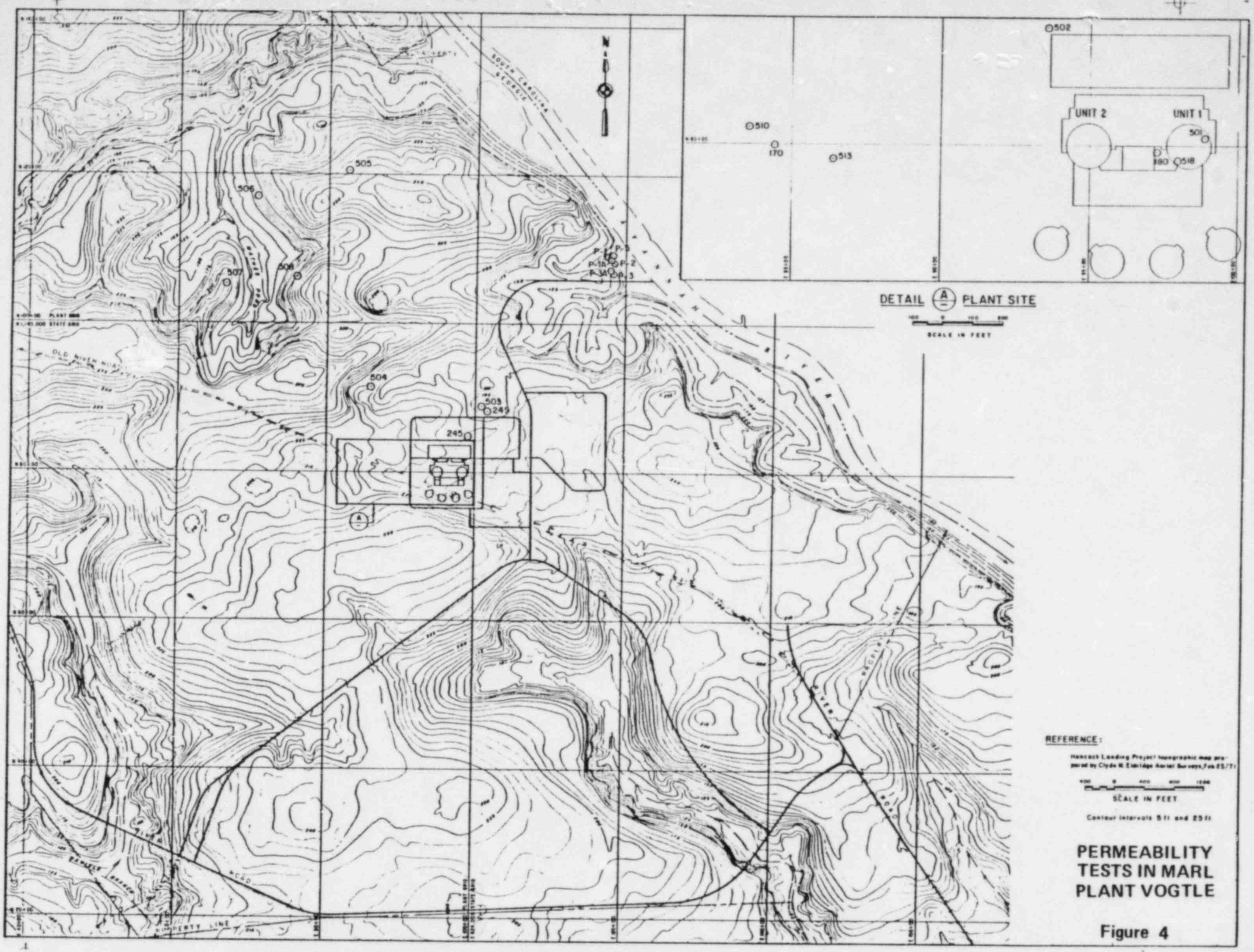
EXPLORATORY HOLES
AND WELLS
THROUGH BLUE BLUFF MARL
PLANT VOGTLE

Figure 3

20. Permeability measurements have been made of the water-table aquifer, the marl, the Tertiary aquifer, and the Cretaceous aquifer. Also, estimates of permeability of the Barnwell sands were made from grain-size analyses of over 20 samples. The lowest strata in the water-table aquifer (the Utley limestone) was studied with pumping tests, falling head tests, and constant head tests in two well arrays. The marl permeability was measured in-situ with 80 packer tests and permeameter tests conducted in 22 drill holes, the locations of which are shown in Figure 4. The hydraulic characteristics of the Cretaceous and Tertiary aquifers were measured in pumping tests.

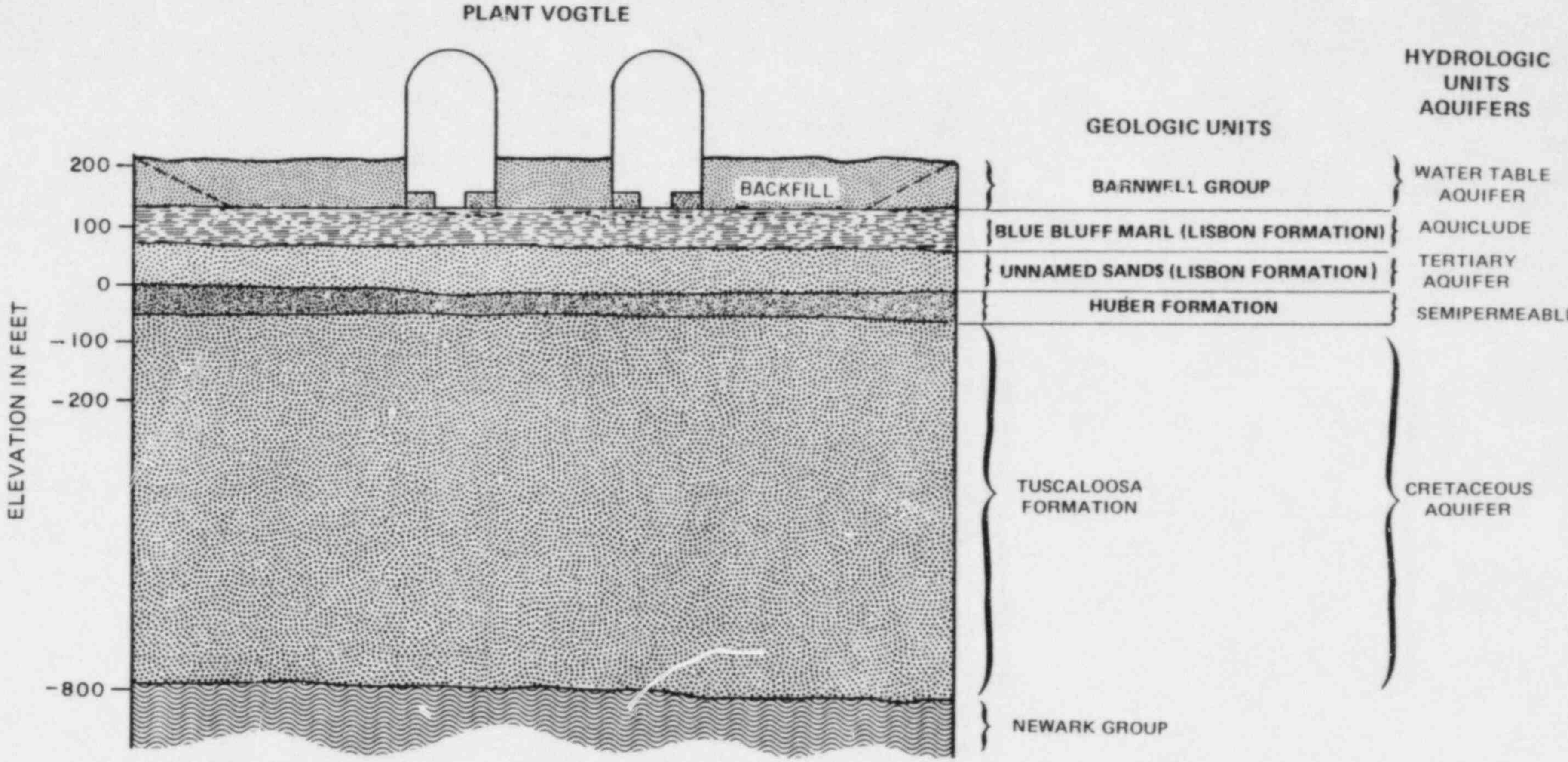
D. The Interrelationship of Geologic and Hydrogeologic Units at Plant Vogtle

21. The extensive investigations at Plant Vogtle have determined the interrelationship of both geologic and hydrologic units as shown on Figure 5. The VEGP site is situated over an area wherein the Huber Formation and the Ellenton, if it is present (Ellenton beds have not been positively identified beneath the site), are thin and relatively permeable. As a result, the Cretaceous and Tertiary aquifers are believed to be hydraulically connected in this area. Overlying this sequence of beds of moderate to high permeability is the Blue Bluff marl, the upper member of the Lisbon Formation. The marl layer, approximately 70-feet thick, is an effectively-impermeable layer that confines the Tertiary and Cretaceous



PERMEABILITY TESTS IN MARL PLANT VOGTLE

Figure 4



SEQUENCE OF GEOLOGIC AND HYDROLOGIC UNITS BENEATH PLANT VOGTLE

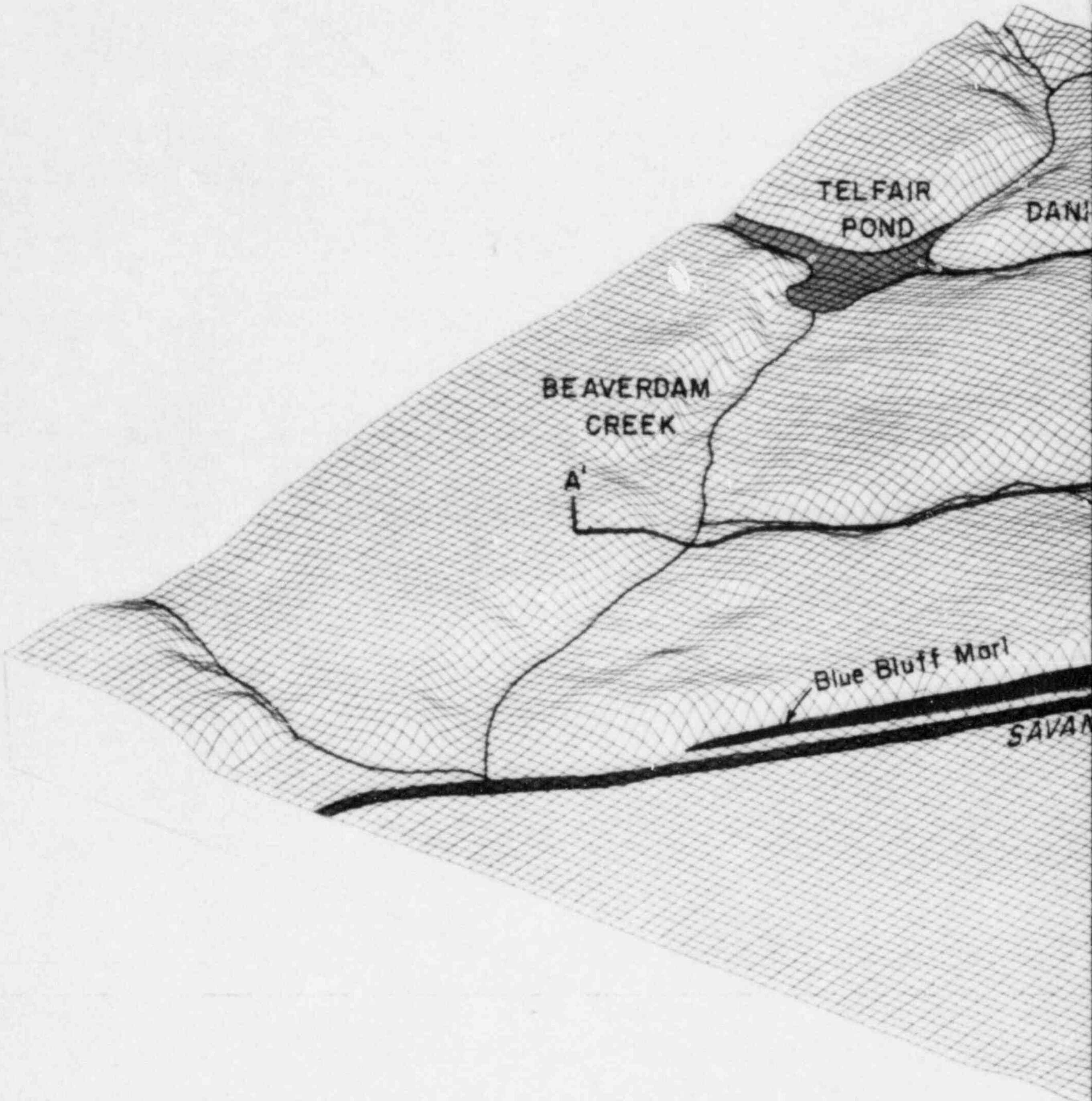
Figure 5

aquifers, and hydraulically isolates the confined aquifers from the overlying water-table aquifer.

22. The Barnwell sands and limestone, which overlie the marl and in which the unconfined water-table aquifer exists at VEGP, are on an interfluvial ridge -- a topographically high area in which the ground-water in the water-table aquifer discharges along streams that nearly surround the area. The interfluvial ridge at VEGP is illustrated in Figure 6. The water-table is, in general, a subdued reflection of the ground surface, and movement is from the central portions of the interfluve toward the bordering interceptor streams. The streams have eroded down to the marl.

23. Along the east flank of the site, the interfluvial ridge ends abruptly at the bluff of the Savannah River. The sands, silts and clayey sands that make up the water-table aquifer beneath the site are exposed in the face of that bluff. More prominently exposed is the underlying unit which gives the bluff its characteristic feature -- the Blue Bluff marl. The exposure is illustrated in Figure 6.

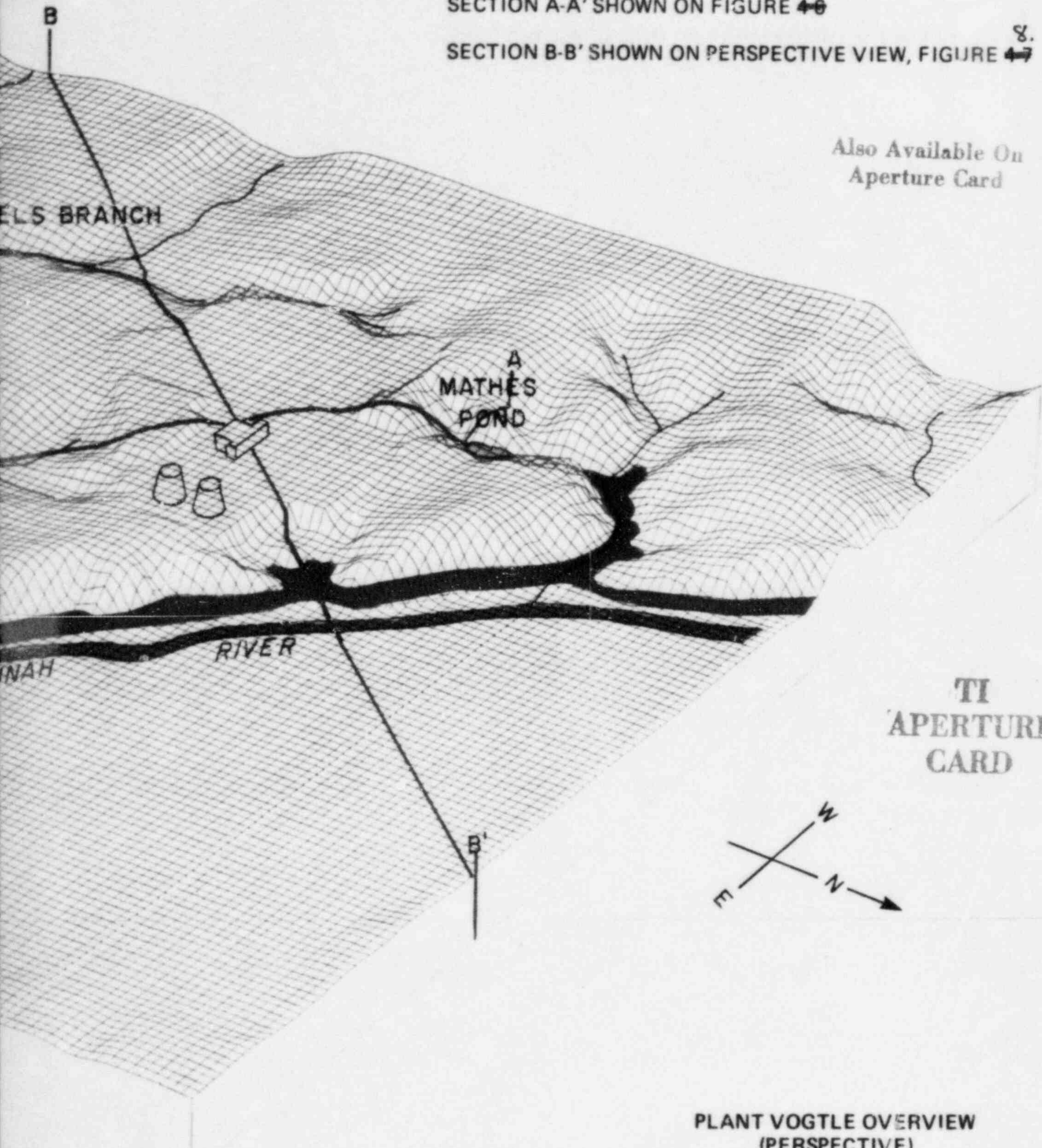
24. Bordering the site on the south, west and north are stream channels tributary to the Savannah River that have cut through the aquifer sands down to the marl. On the north is the drainage of Mathes Pond, which discharges to the Savannah River at Hancock Landing. The marl is exposed at Mathes Pond, and in the channels downstream to the river (See Figure 7). South and west of the site is Beaverdam Creek and its major



TELFAIR
POND
BEAVERDAM
CREEK
A'
Blue Bluff Marl

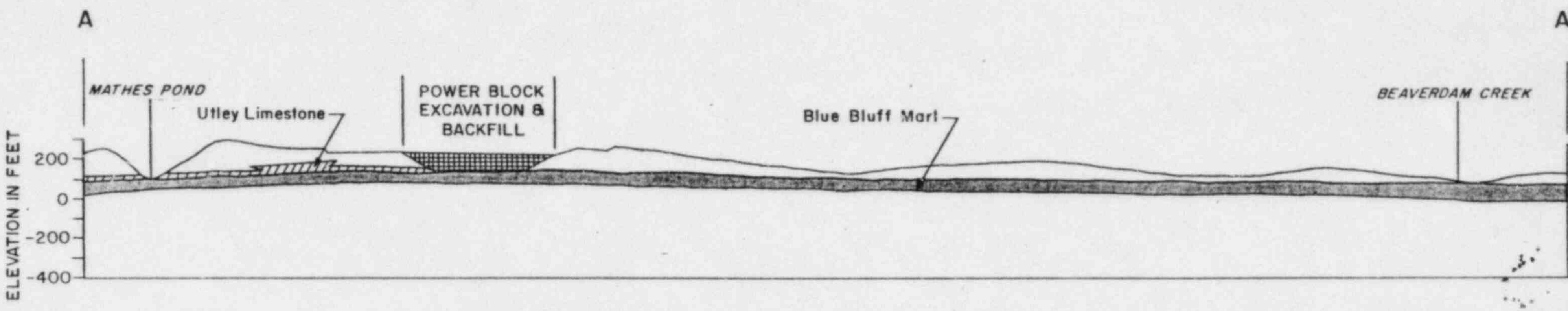
SECTION A-A' SHOWN ON FIGURE ~~4-6~~ 7.

SECTION B-B' SHOWN ON PERSPECTIVE VIEW, FIGURE ~~4-7~~ 8.



PLANT VOGTLE OVERVIEW
(PERSPECTIVE)

Figure 6



NOTES:

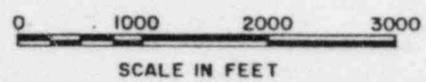
1. See Figure 4-5 for location of section
2. (Modified from Vogtle FSAR Figure 2.5.1-15 Geologic Section B-B')

PLANT VOGTLE

SECTION A-A'

MATHES POND TO BEAVERDAM CREEK

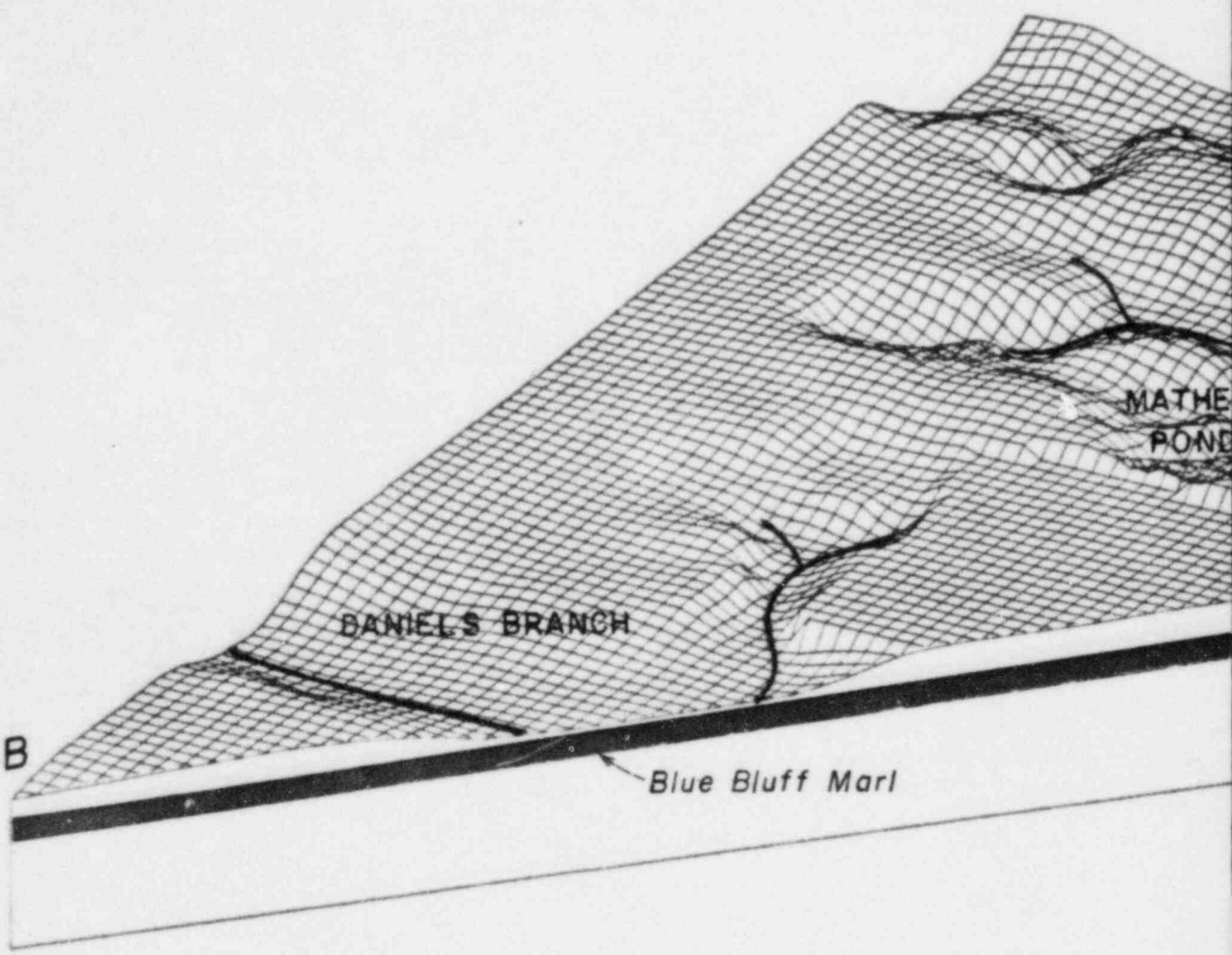
Figure 7



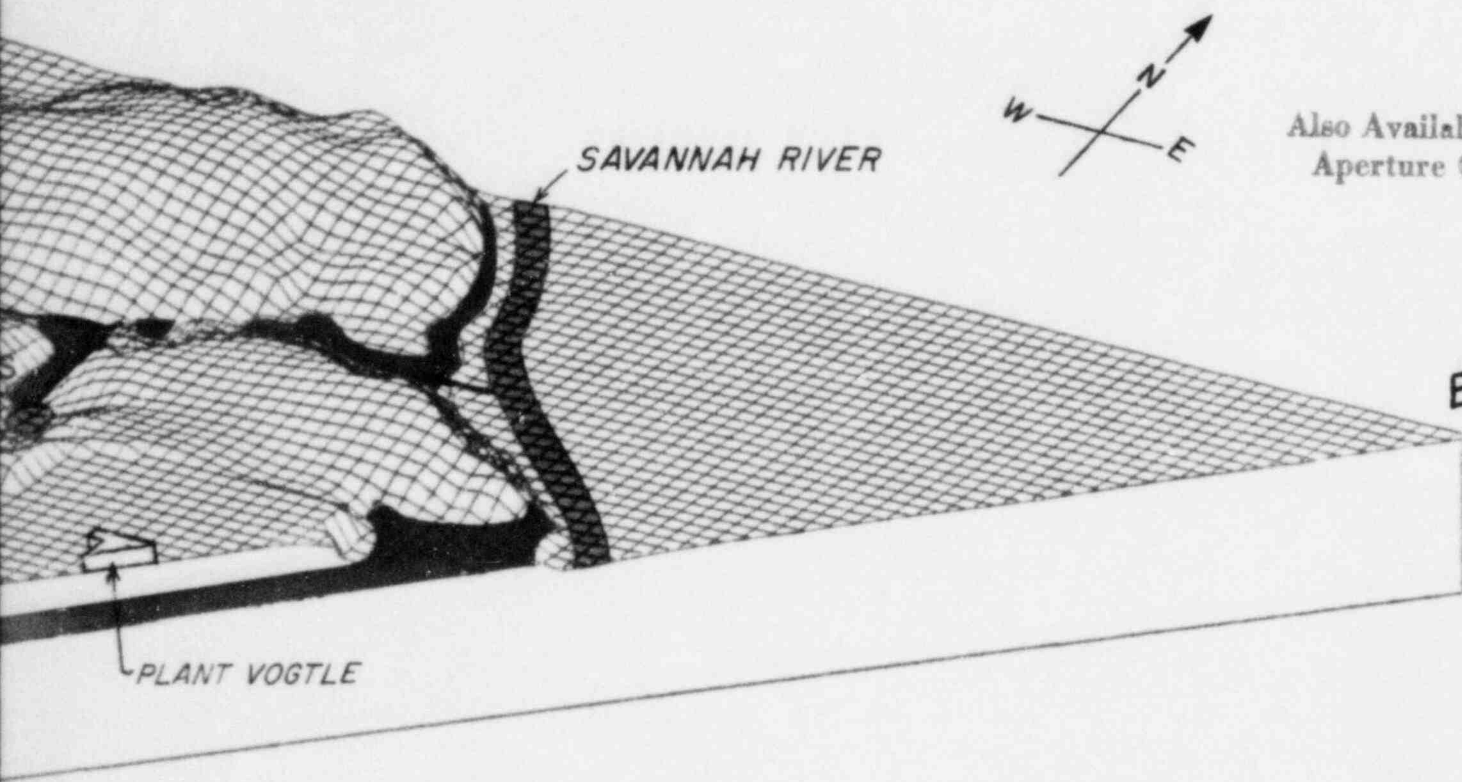
tributary, Daniels Branch. The marl is present in these channels just below alluvial channel deposits. Extending northward from these named streams are tributaries bordering the site; the marl is also present immediately below a veneer of channel deposits in these tributaries. The presence of the marl immediately below these channels was determined by exploratory holes and is illustrated in the geologic section of Figure 8. There is only a narrow remnant of continuity between the water-table aquifer materials beneath the site and those offsite. That remnant is northwest of the plant between the head of the Mathes Pond drainage and the unnamed tributary to Daniels Branch west of the plant. Ground-water beneath the narrow remnant drains either into Mathes Pond or into the unnamed tributary of Daniels Branch. Thus, the water-table aquifer at VEGP is isolated, both laterally and vertically, from other aquifers.

II. <u>The Consequence of an Accidental Spill</u>

25. In the very unlikely event that an accidental spill of radioactive fluid occurred at Plant Vogtle and infiltrated the ground without interception, it could percolate downward until it reached the water-table (unconfined) aquifer. The underlying Blue Bluff marl, however, would prevent further vertical movement of contaminant, preventing the contaminant from reaching the deeper Tertiary/Cretaceous (confined) aquifers. Any further migration would be lateral and in the direction of



MATHE
POND
DANIELS BRANCH
B
Blue Bluff Marl



SECTION B-B'
PLANT VOGTLE OVERVIEW

Figure 8

decreasing hydraulic head. Accordingly, a spill would flow northward toward, and after considerable travel time discharge into, Mathes Pond and stream, as further discussed below.

A. The Effectiveness of the Marl as a Barrier Against Contamination Reaching the Tertiary/Cretaceous Aquifers

26. The Blue Bluff marl is a densely-consolidated, fine-grained calcareous clay. The reported values of the permeability of unweathered marine clays, of which the marl is a type, range from 10^{-7} to 10^{-10} cm/sec (0.1 to 0.001 ft/year). In engineering practice, materials with such low permeability are qualitatively considered to be impermeable.

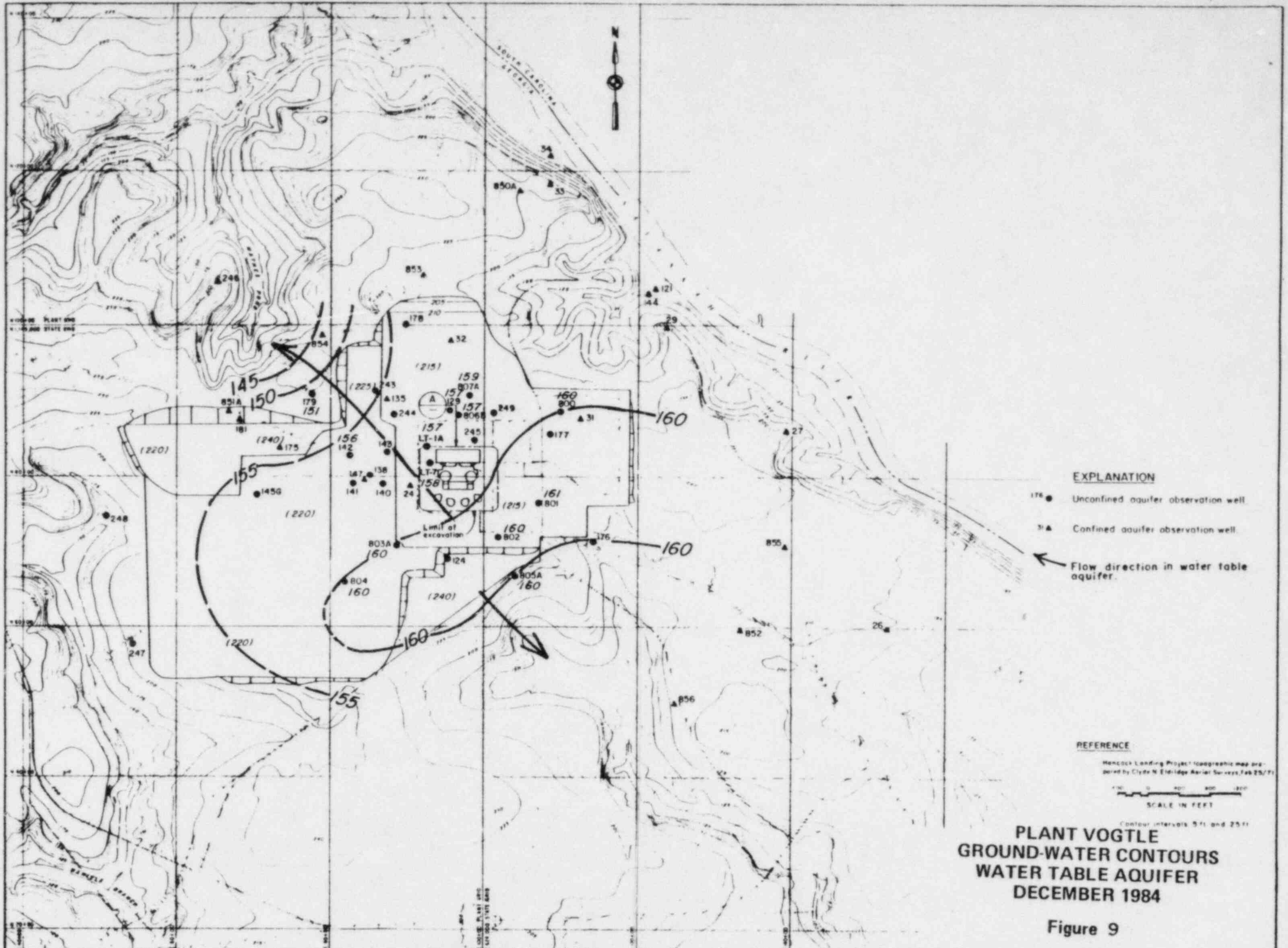
27. The Blue Bluff marl is approximately 70 feet thick. It extends over an area well beyond the limits of the plant site and the interfluvial ridge on which the plant site is located. The comprehensive exploration and testing that has been conducted demonstrates that the marl is an extensive and persistent unit that will effectively prevent any fluids from percolating downward to the underlying Tertiary/Cretaceous aquifers. In particular, the marl's integrity as a barrier to ground-water movement has been demonstrated by (1) field permeability testing, (2) visual inspection of cored samples, the marl surface exposed during site excavation, and marl outcrops along the Savannah River, and (3) comparison of water levels in observation wells open to the water-table aquifer with those observed in wells open to the confined aquifer immediately below the marl.

28. The permeability of the marl was measured in the field at 80 intervals of varying depth in 22 exploratory holes. Constant-head inflow methods were used. In 20 of the exploratory holes, inflatable packers were used to isolate a specified test interval. These tests followed the procedure set out in Designation 18 of the U.S. Bureau of Reclamation Earth Manual. In two exploratory holes at the intake structure, permeameter tests were conducted in accordance with Designation 19 of the U.S. Bureau of Reclamation Earth Manual. In nearly all of the intervals tested, no measurable water inflow occurred. In only three holes was any measurable water intake confirmed, two of which were in near-surface, weathered marl at the intake surface. (Water inflow was measured in three other holes, but was due to leakage around the packers.) These tests indicate that the marl is effectively impermeable.

29. The continuity of this impermeable material (i.e., the lack of voids, open joints or fractures) has also been demonstrated. Since 1971, there have been over 10 thousand feet of marl penetrated at VEGP by drilling, coring, Standard Penetration Testing, and undisturbed sampling. At no time throughout this extensive testing was there any unaccountable fluid loss or abnormal tool advance in the marl. When coring, the most revealing evidence for the occurrence of voids or fractures is a loss of all or part of the drilling fluid and/or a sudden or rapid advance of the core barrel. Neither of these conditions occurred during the site exploration. None of the

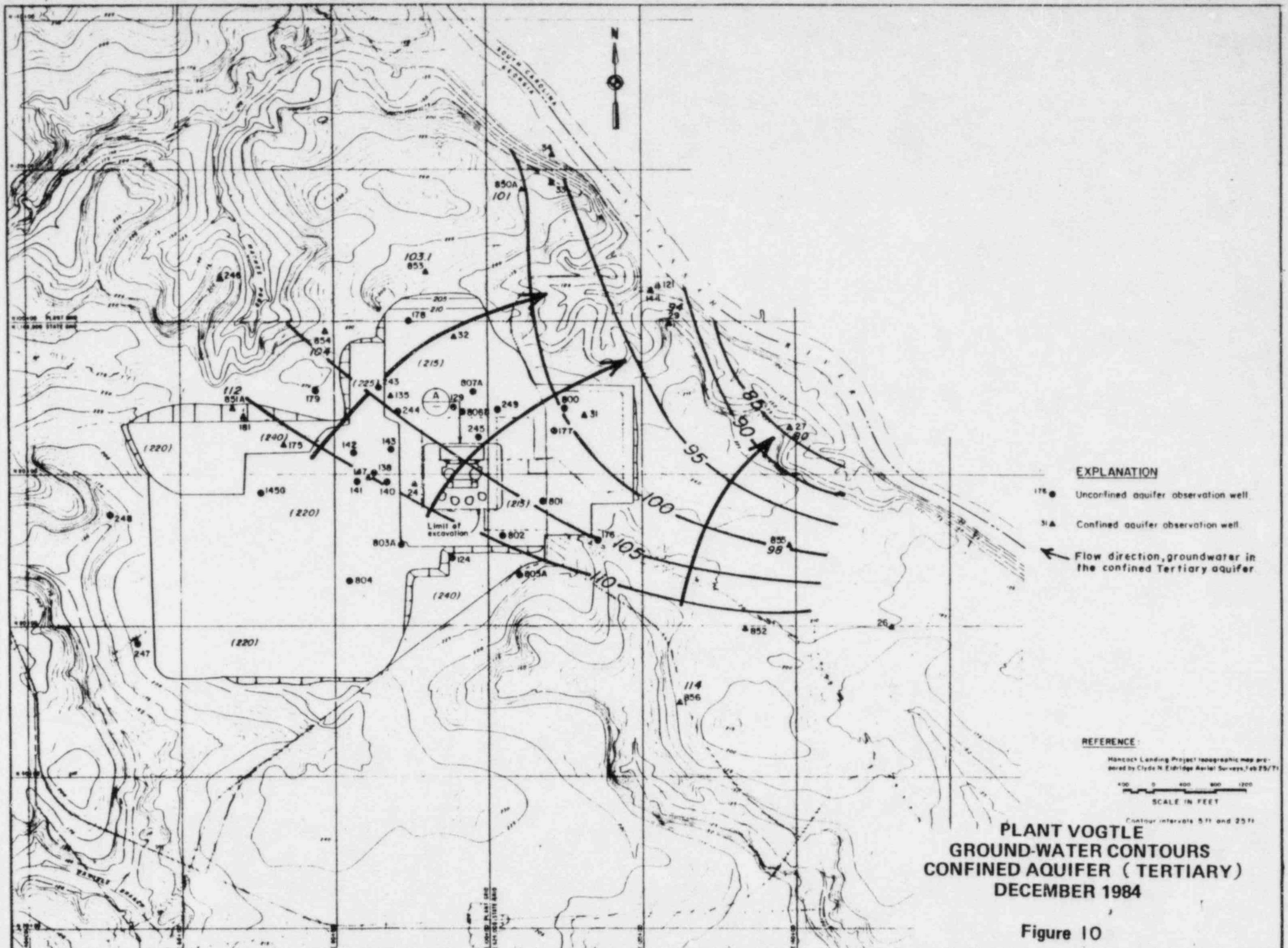
borings encountered significantly fractured zones; nor was there evidence of leaching (removal of calcareous material.)

30. Visual inspections and detailed logging and photographing of the many extracted samples of marl have likewise produced no indications of voids or extensive fracture zones. Over 500 feet of the marl penetrated has been collected either by coring or sampling and closely inspected and described. Very few joints or fractures were observed and those identified were consistently found to be tight, and without void space. Marl beneath the plant site, exposed during excavation for the foundation, was directly examined and carefully logged by qualified geologists. This included inspection and logging of more than 900,000 square feet of the upper surface of the marl at the base of the power block excavation, more than 20,000 square feet of detailed mapping and photographing of vertical face in the auxiliary building excavation, and more than 20,000 square feet of inspection and logging of the vertical face in the radwaste solidification building caisson excavations. Additionally, marl outcrops along the Savannah River in the vicinity of VEGP have also been examined, mapped and photographed. These extensive and detailed mapping investigations of the marl formation at VEGP have produced an abundance of data to support the conclusions that there are no voids or solution cavities in the marl and that there are no systematic or extensive fractures or joint sets in the marl.



PLANT VOGTLE
GROUND-WATER CONTOURS
WATER TABLE AQUIFER
DECEMBER 1984

Figure 9



PLANT VOGTLE
GROUND-WATER CONTOURS
CONFINED AQUIFER (TERTIARY)
DECEMBER 1984

Figure 10

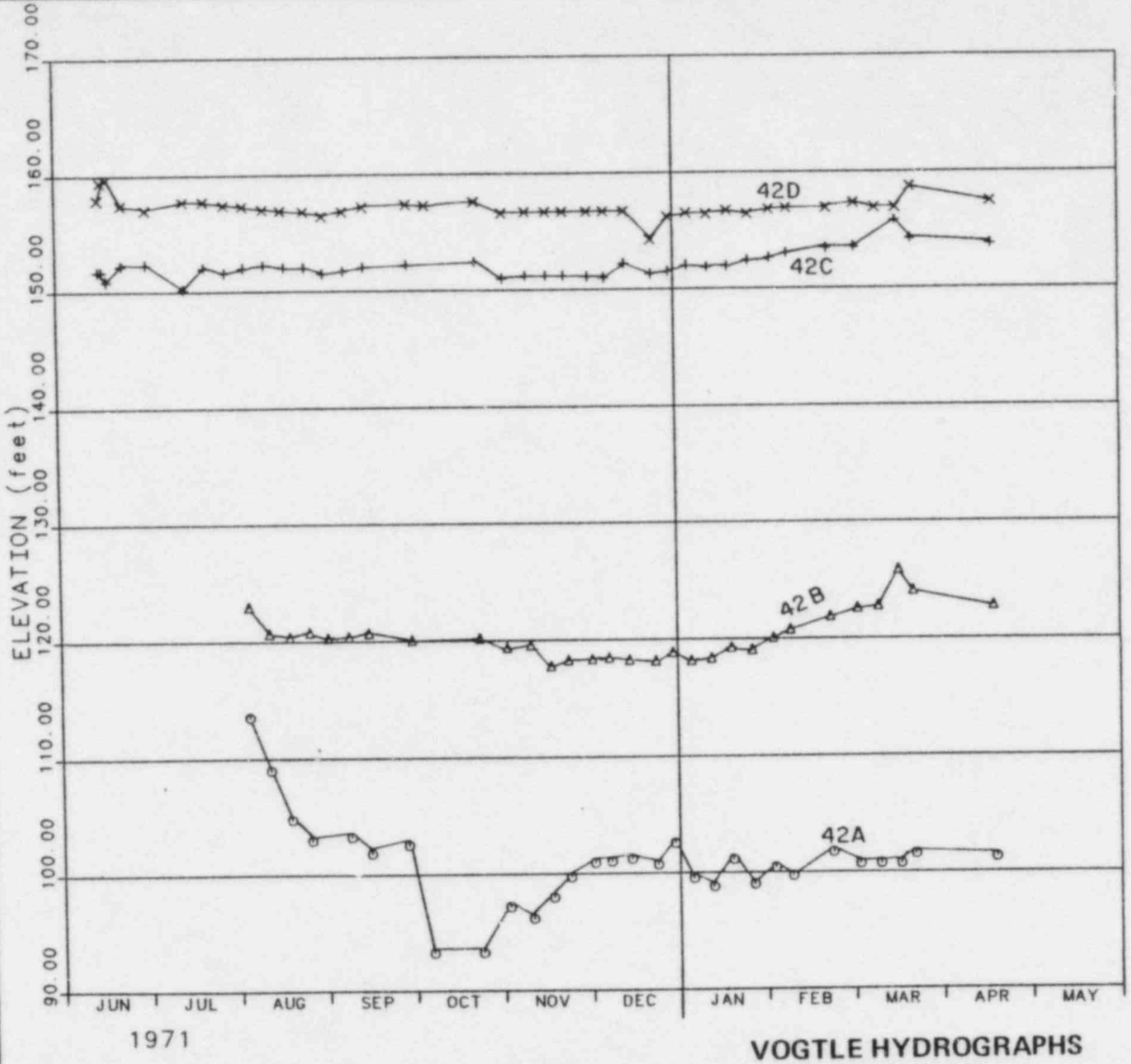
31. Finally, the large and consistent hydraulic head differential between the water-table aquifer and the confined aquifers immediately below the marl confirms that the marl is a barrier to ground-water movement. The hydraulic head (energy potential) of ground-water in an aquifer is commonly expressed as feet (elevation) above sea level, and is determined from measuring the elevation of water in an observation well. In the vicinity of the plant, the hydraulic head in the water-table aquifer is 45 to 55 feet greater than the hydraulic head in the aquifer immediately below the marl. This difference in hydraulic head can be seen by comparing the ground-water (equipotential) contours shown on Figures 9 and 10. The contours are based on water levels measured in observation wells in December, 1984. Similar conditions were observed prior to plant construction, as indicated by the contours of water levels measured in wells in November 1971 and shown in Figures 2.4.12-6 and 2.4.12-7 in the FSAR. To bring about such a marked difference in hydraulic head, the barrier must be extensive and without significant through-going openings (such as fractures or solution cavities).

32. A nest of observation wells constructed at the site of exploratory hole 42 provided a direct measure of this hydraulic head differential between the overlying water-table aquifer and the confined aquifer sands beneath the marl. The observation wells were constructed in 1971 and included two, 42B and 42C, open to the marl itself, and one each, 42A and

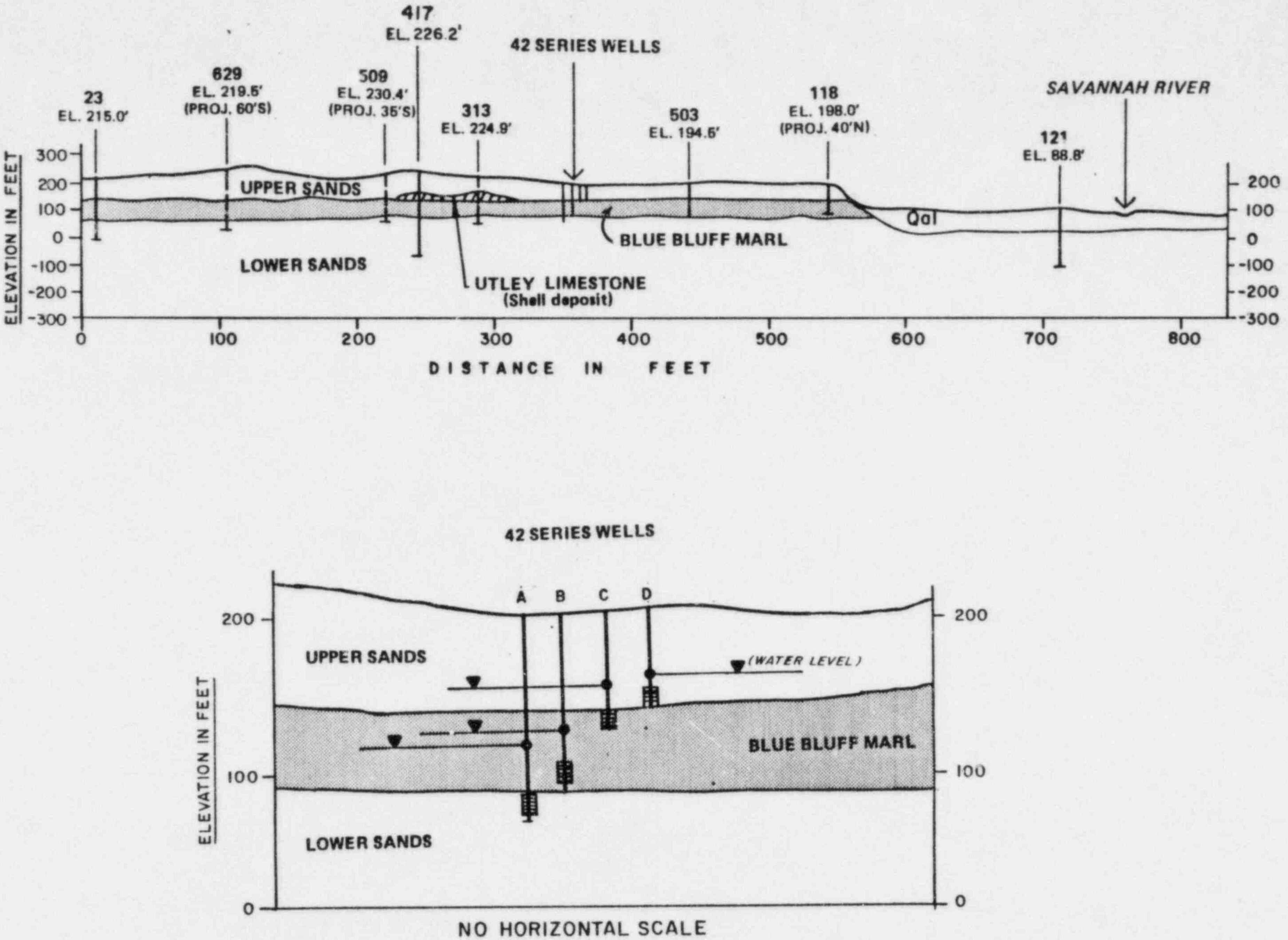
42D, that were open to the confined and water-table aquifers, respectively. At their location, the marl is 65 feet thick. The wells were monitored for four years until construction of the plant required their closure, at which time they were sealed. Hydrographs of the measured levels are shown in Figure 11.

33. The differences in water levels (head) between the observation wells is generally proportionate to the thickness of marl between the wells. The zones monitored by each observation well are illustrated on Figure 12. For example, the difference in water levels of the two wells open to the two aquifers (42D and 42A) is about 55 feet, (the head in the water-table aquifer is higher) and the thickness of marl between them is 65 feet. In comparison, well 42B is open to an interval of the marl that is near the bottom of the marl. The water levels measured in well 42B are from 15 to 20 feet different (higher) than those measured in well 42A, which is open to the underlying confined aquifer, and the thickness of marl between them is about 10 feet. Water levels measured in well 42C follows this general relationship. It is open to an interval of the marl that is within 3 feet of the top of the marl. The water levels measured in 42C are from 50 to 52 feet higher than those measured in 42A, and the thickness of marl between them is about 60 feet.

34. It should be noted that the presence of water in the observation wells open to the marl does not indicate a rate of



VOGTLE HYDROGRAPHS
42 SERIES WELLS
Figure 11



SECTION SHOWING 42 SERIES WELLS

Figure 12

water inflow to the well or cast any doubt on the effective impermeability of the marl. The water levels in the well reflect the hydrostatic pore pressure in the monitored interval of the well. Fluctuations of levels in the wells can be a response to changes in hydrostatic loading, which result from a number of causes including changes in atmospheric pressure, or changes in head within the adjacent aquifer.

B. <u>Lateral Migration and the Hydraulic Isolation of the VEGP Site</u>

35. Because the marl is effectively impermeable and prevents vertical movement of contaminants, migration of contaminants from an accidental spill at VEGP would be lateral in the direction of decreasing head in the water-table aquifer. The water-table has been monitored by measurements of levels in wells at the VEGP site since 1971. With these measurements, contours of ground-water levels can be constructed and the direction of ground-water flow determined. The direction of ground-water flow beneath the power block area is northward to Mathes Pond as shown in Figure 9.

36. Ground-water moving northward from beneath the power block area will eventually reach Mathes Pond. Concentrations of any remnant radionuclides from a spill at the plant would be further reduced by dilution as the contaminated ground-water slowly discharged into Mathes Pond (which is completely on-site) and, subsequently, to the stream. Ground-water north of Mathes Pond and stream would not be affected. The Mathes

drainage has cut down to the marl, as have other streams bordering the interfluvial ridge on which VEGP is located, interrupting continuity between water-table aquifers. Ground-water in the water-table aquifers on both sides of the bordering pond and streams discharges into the pond and streams (i.e., ground-water flows into and not across the pond and streams).

37. Because the water-table aquifer beneath the VEGP site is hydraulically isolated (see discussion on pages 9-11), an accidental spill could not impair domestic or other wells beyond the interfluvial ridge. For the same reason, a spill could not migrate to an area where the marl is not present or less permeable (potential avenues to reach the lower, confined aquifers).

38. The only wells that could be affected by an accidental spill are those on the interfluvial ridge and drawing from the water-table aquifer. There is only one such well. This well is located approximately 1.7 miles south of the plant. Ground-water, however, does not flow south from the plant but north, to Mathes Pond, as described above.

C. Spill Analyses and Travel Time Estimates

39. Several analyses have been made to assess the impact of a postulated spill. Applicants have analyzed the impact of the rupture of the Recycle Holdup Tank (RHT) -- the tank that potentially has the highest specific isotopic activity (highest concentration of radioisotopes). FSAR §§ 2.4.13, 15.7.3. The

NRC Staff references this analysis in the FES as representing a worst case release for potential offsite impact of design basis events. FES-OL, § 5.3.2.4. The NRC Staff also performed a similar analysis for the rupture of the Waste Evaporator Concentrates Holdup Tank (WECHT), which is a smaller tank than the RHT but which has a specific isotopic activity comparable to that of the RHT. SER, § 2.4.13. In addition, both Applicants and the NRC Staff have analyzed a core-melt liquid-pathway accident scenario. ER-OL, § 7A; FES-OL, § 5.9.4.5(4). Each of the analyses is based on a simplified, one-dimensional flow model in which a number of conservative assumptions are made. The analyses differ in the hydraulic gradient, permeability, and effective porosity assumed along the ground-water flow path. The different analyses consider either best-estimate values of flow path parameters or worst-case values of flow path parameters.

40. All of the analyses impose extreme assumptions involving the manner in which a radioactive release could occur. With respect to an accidental spill, the RHT and WECHT are the most critical tanks. In order to consider the effects of a release of the contents of either the RHT or the WECHT to the ground-water, the spill analyses necessarily postulate not only tank failure, but also the failure of the auxiliary building in which these tanks are located. The spill analyses assume that these failures are total and that the release to the ground-water occurs instantly, with no dilution of the spilled

waste; the spill is transferred to the ground-water as a slug in negligible time (no decay).

41. Following these postulated events, the spilled waste would migrate along a flow path in the ground-water northward to Mathes Pond. The flow path considered is a straight-line between the auxiliary building and the spring on the southeast side of Mathes Pond, a distance of 3400 feet. Based on Applicants' best estimates, Applicants' calculated the migration time between the power block and Mathes Pond to be approximately 350 years. Radionuclide decay during this long period is more than sufficient to reduce all radionuclide concentrations in a worst-case spill to below 10 C.F.R. Part 20 limits by the time the spill reaches Mathes Pond.

42. The core-melt liquid-pathway analysis described by the NRC in the FES-OL imposes the most conservative assumptions, resulting in the shortest calculated time for ground-water beneath the power block to reach Mathes Pond (15 years). In that analysis, the time of travel through the major portion of the flow-path to Mathes Pond is not considered. Only that portion within the backfill material, a distance of 550 feet is evaluated. Outside the backfill material, it is assumed that travel is rapid in an undefined conduit within the Utley limestone.

43. The NRC applied the same extreme assumption to its analysis of a rupture of the WECHT. As demonstrated below, if one applies this assumption to an analysis of the rupture of

either the WECHT or RHT, such analysis still demonstrates that 10 C.F.R. Part 20 limits will not be exceeded off-site.

44. The time required for ground-water to migrate through the backfill is determined by the permeability and porosity of the materials, and the hydraulic gradient. The permeability assigned to the backfill is the maximum value (2260 ft/yr) reported from laboratory tests, and the effective porosity is a minimum value (25%), based on laboratory tests. The test data are presented in the Ground Water Supplement. Selecting maximum permeability and minimum porosity values, rather than average or best-estimate values, poses further conservatism (i.e. reduces travel time). The hydraulic gradient, reported as 0.004, is determined by the change in ground-water level along the flow path (see Figure 9). The relationship between these parameters in determining ground-water seepage velocity is expressed as Darcy's Law:

$$v = \frac{Ki}{N_e}$$

where, v = seepage velocity (L/T),

K = coefficient of hydraulic conductivity (permeability) (L/T),

i = hydraulic gradient (ratio)

N_e = effective porosity (ratio)

45. Applying the parameter values described, the calculated ground-water velocity in the backfill is 36.2 ft/yr. With a flow path length of 550 feet, the ground-water travel time in the backfill is 15 years.

46. The concentrations of spilled radionuclides that are ultimately transmitted through a ground-water system to a discharge point (i.e. through the water-table aquifer to Mathes Pond and stream, and, subsequently, discharged off-site to the Savannah River) is determined by the following factors:

- The source (tank) radionuclide inventory released to the ground-water
- The attenuation which takes place during transport through the system, caused principally by dispersion, dilution, adsorption, and radioactive decay.

47. Of the several radionuclides present in the liquid waste holding tanks, three are critical because of relatively long half-lives. These include tritium (H-3), strontium-90 (Sr-90), and cesium-137 (Cs-137). Because they are chemically active and susceptible to adsorption, migration of Sr-90 and Cs-137 in the ground-water will be retarded; they will move at a markedly slower rate than the water. Tritium is not adsorbed significantly, and tends to travel at the same rate as the ground-water

48. The degree of retardation is governed by the various physical properties such as bulk density, aquifer porosity, and radionuclide equilibrium coefficients. The relationship between ground-water velocity (or ground-water transport time), radionuclide adsorption, and the radionuclide fraction resulting from decay that is ultimately transmitted to Mathes Pond is given by the following expression:

$$\ln (T.F.) = \frac{-0.693(t)a}{T_{1/2}}$$

where, T.F. = transmitted fraction (ratio)

t = estimate of ground-water travel time (T),

a = adsorption retention factor,

$T_{1/2}$ = radionuclide half-life (T).

49. The adsorption retention factor (also called retardation factor) is equal to $(1 + p/n\ K_d)$

where, p = bulk density of the aquifer

n = porosity of the aquifer

K_d = equilibrium distribution coefficient which is defined as the mass of radionuclide adsorbed per gram of soil divided by the mass of radionuclide dissolved per milliliter of groundwater

50. A typical value of the ratio, p/n is 5; however for consistency with the NRC assessment, the value of 4.1 is adopted. The equilibrium distribution coefficients used in this analysis are those presented by the NRC Staff in FES Section 5.9.4.5. These equilibrium distribution coefficients were derived from an extensive literature search and are at the low end of the range of values given by Isherwood (NUREG/CR-0912, January 1981). The following presents the equilibrium distribution coefficient, calculated retardation factor, half-life, and calculated transmitted fraction for each of the significant isotopes, assuming a ground-water travel time of 15 years.

Nuclides	Kd(cm3/gm)	a	T 1/2 (yr)	TF
H-3	0	1	12.1	4.2E-1
Sr-90	5	21.5	28	3.0E-4
Cs-137	49	201.9	30	4.1E-31

51. The concentration of radioisotopes in contaminated ground-water after travel through the backfill is equal to the transmitted fraction times the initial concentration. The following summarizes the expected initial concentrations assumed to be present in the postulated spill, the reduced concentration after travel through the backfill due to radioactive decay and absorption, and the maximum permissible concentration (MPC) for normal releases from 10 C.F.R. Part 20, Appendix B (Table II, Column 2).

Postulated RHT Rupture

Nuclides	Initial Activity (μCi/cm3)	Concen. after Travel through Backfill (μCi/cm3)	MPC (μCi/cm3)
H-3	1.0E-0	4.2E-1	3.0E-3
Sr-90	1.0E-5	3.0E-9	3.0E-7
Cs-137	1.9E-2	7.8E-33	2.0E-5

Postulated WECHT Rupture

Nuclides	Initial Activity (μCi/cm3)	Concen. after Travel through Backfill (μCi/cm3)	MPC (μCi/cm3)
H-3	1.0E-0	4.2E-1	3.0E-3
Sr-90	8.9E-6	2.7E-9	3.0E-7
Cs-137	1.7E-2	7.0E-33	2.0E-5

52. It can be seen that under this very simplified and conservative scenario, the concentrations of both Sr-90 and Cs-137 in ground-water would meet 10 C.F.R. Part 20 limits after travel through the backfill. Parameters that would reduce the concentration further, such as dispersion and dilution, need not be considered. Because H-3 is not retarded and migrates with the ground-water, the tritium concentration in ground-water travelling through the backfill would exceed the MPC limits (still ignoring any dilution or dispersion of the spill).

53. Contaminated ground-water subsequently reaching Mathes Pond, however, would be further diluted in the pond and in the stream running from the pond to the Savannah River, reducing the concentration below 10 C.F.R. Part 20 limits before it flows off-site. Flow into Mathes Pond is continuous, and the pond level remains constant. The rate of flow in the stream draining Mathes Pond has been calculated to be 250 gpm from inspection.

54. The ratio of Mathes Pond stream flow to the rate at which the postulated spill would discharge from the backfill (and into Mathes Pond) is the potential for dilution of the spill within the stream. The discharge rate of the spill in the backfill is determined by the velocity of ground-water flow (36.2 ft/yr) and the assumed volume and dimensions of the spill slug. Of the two critical sources of radionuclides in an accidental spill (the RHT and the WECHT), the larger volume is

contained within the RHT (total capacity of 112,000 gallons). Assuming the tank is filled to 80 percent of its total capacity, its entire content is released, and the spill is instantly transferred to the backfill, the rate of discharge from the backfill would be from 0.08 to 0.14 gpm, depending on the dimensions of the spill.

55. The volume of flow in Mathes Pond stream would reduce the concentration of the largest calculated discharge rate (0.14 gpm) by a factor of more than 1700. The concentration of tritium discharging from the backfill (0.42 µCi/cm3) would be reduced to 2.4 x 10^{-4} in the Mathes Pond stream with complete mixing. Because contaminated ground-water would first discharge to the Pond, and would then flow into and down the stream below the Pond before discharging offsite, there would be adequate mixing. However, assuming only a 50 percent effective mixing, the concentration of tritium in Mathes Pond and steam would be 4.8 x 10^{-4} µCi/cm3, which is below permissible concentration levels.

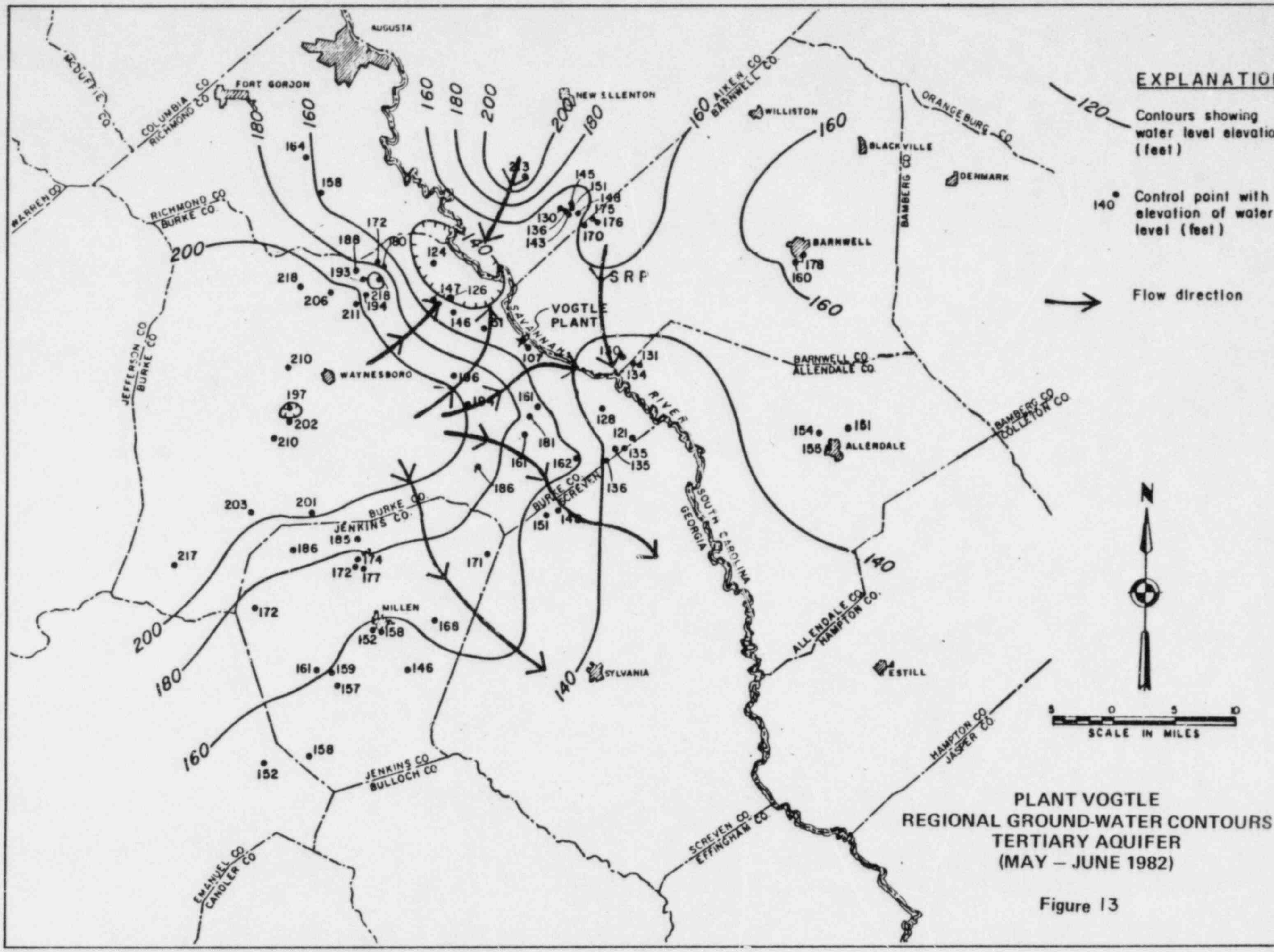
56. It bears repeating that the analysis above is extremely conservative. It assumes an instantaneous release to the ground-water, and thereby ignores any initial dilution or decay. It ignores all travel time beyond the backfill. It ignores dispersion of the spill during its migration to Mathes Pond; and it ignores dilution due to the percolation of precipitation during the travel time. Applicants' 350 year estimates is more realistic. Nevertheless, even if one adopts the

extreme assumptions inherent in the NRC staff's analysis of a core-melt liquid-pathway accident scenario and applies them to a worst-case spill, it is still evident that 10 C.F.R. Part 20 limits will not be exceeded off-site.

D. The Savannah River as a Pathway to the Confined Aquifers

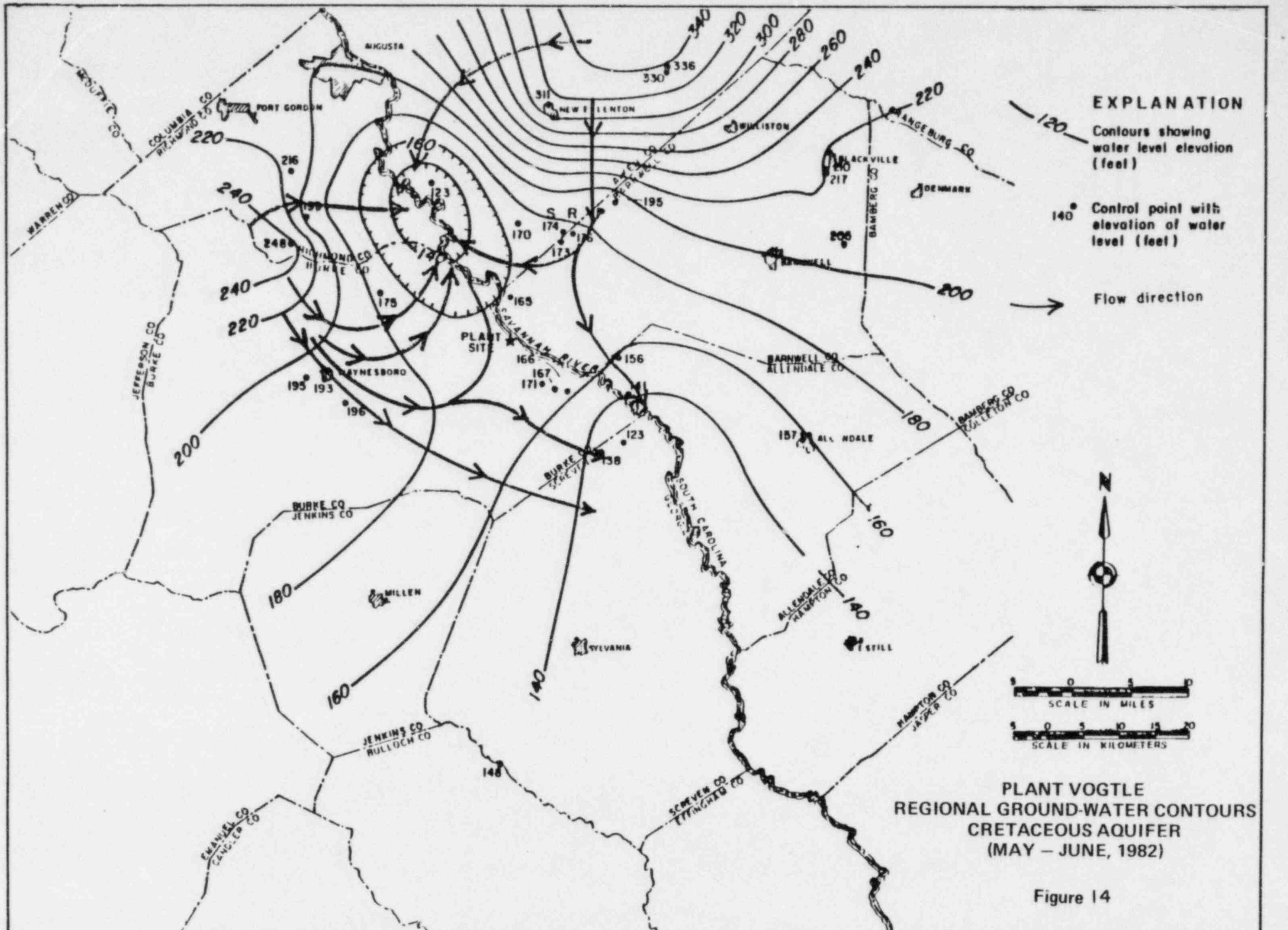
57. Exploratory holes along the Savannah River channel and at the intake structure indicate that the marl unit has been breached (eroded) by the Savannah River. Joint Intervenors have suggested that the Savannah River could thus serve as a pathway for the transmission of contaminants from the water-table aquifer at VEGP to the confined aquifers below. See Campaign for a Prosperous Georgia/Georgians Against Nuclear Energy Third Set of Interrogatories and Request to Produce (Jan. 9, 1985) at 13. The confined aquifers, however, discharge to the Savannah River (i.e., water flows out of the confined aquifers, not into them), as shown in Figures 13 and 14.

58. The direction of flow from the confined aquifers to the Savannah River will persist. In the Atlantic Coastal Plain it has been estimated that from 40 to 95 percent of stream flow is maintained by rejected ground-water recharge that discharges to the streams (Cederstrom, et al., 1979, p. 9). Unless quantities in excess of the rejected recharge are extracted by wells (ground-water use) or are diverted from the aquifers by some other means, the direction of flow will continue to be from the aquifers to the river. The amount of extractions that



PLANT VOGTLE
REGIONAL GROUND-WATER CONTOURS
TERTIARY AQUIFER
(MAY – JUNE 1982)

Figure 13



PLANT VOGTLE
REGIONAL GROUND-WATER CONTOURS
CRETACEOUS AQUIFER
(MAY – JUNE, 1982)

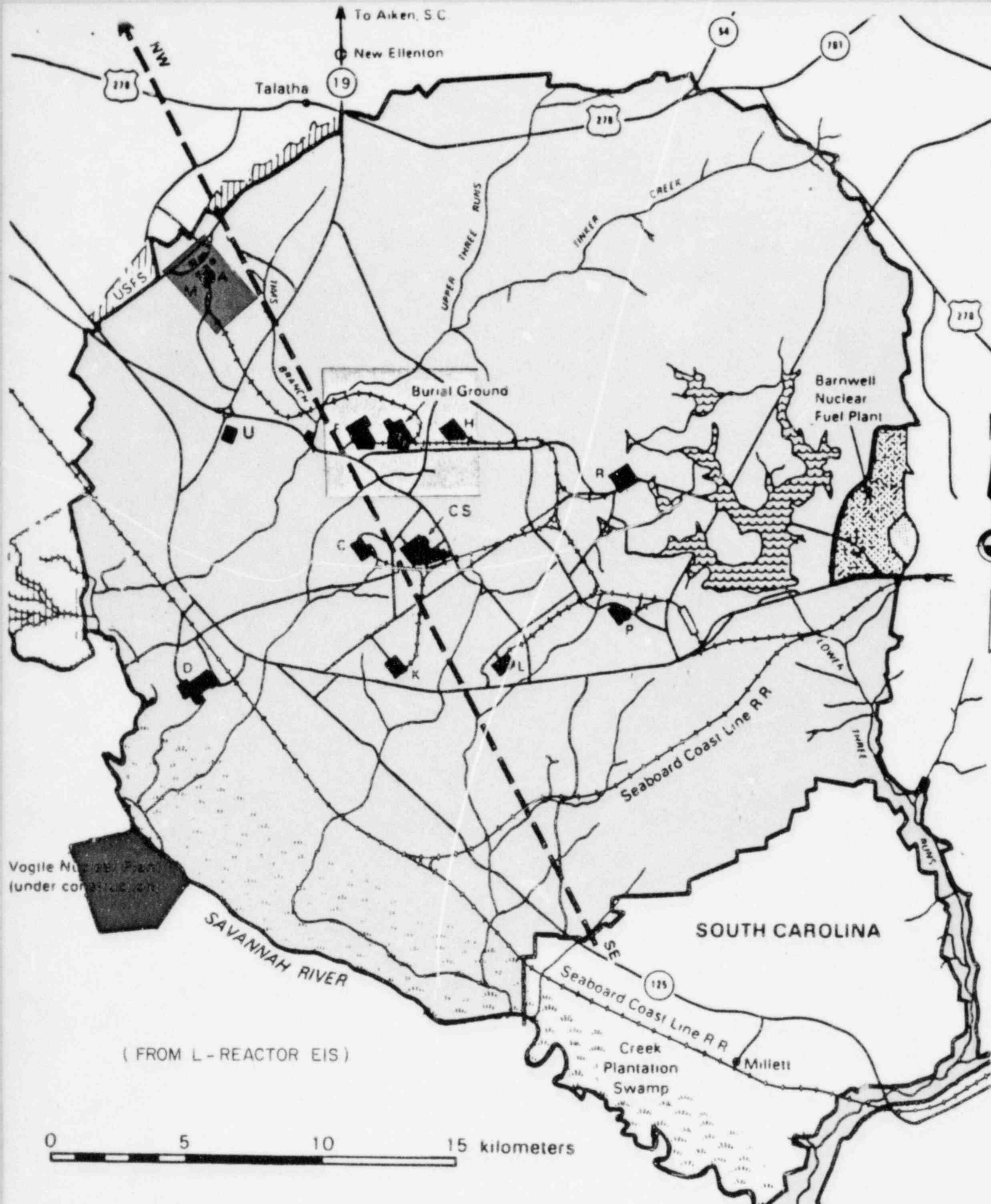
Figure 14

would be required to stop this discharge from the Cretaceous aquifer has been estimated to be 20 bgd (billion gallons per day) (Callahan, 1964, p. 14). Comparable quantities of rejected recharge are discharged to the rivers by the Tertiary aquifers.

59. Present and projected future utilization of ground-water are only a small percentage of these quantities. For illustration, the withdrawal of fresh and saline ground-water for all uses from all aquifers (not just the Cretaceous) of the Gulf Coast, as well as the Atlantic Coast plains region, was a total of 5.5 bgd in 1975 (Cederstrom, et al, 1979, p. 10). It is apparent the quantities of ground-water available in the confined aquifers of the coastal plain preclude the likelihood of a reversal of flow direction between the Savannah River and the underlying aquifers.

III. Ground-water Contamination at the Savannah River Plant

60. As a basis for Contention 7, Joint Intervenors referred to recent contamination of the Cretaceous (Tuscaloosa) aquifer at the Savannah River Plant (SRP). See LBP-84-35, 20 N.R.C. 887, 899 (1974). The only reported contamination of the Cretaceous aquifer at SRP has been the detection of chlorinated hydrocarbons in wells in the A-Area (see Figure 15), particularly wells 53A and 20A. The volatile organics detected apparently came from waste seepage basins at the SRP site. These seepage basins slowly discharge liquid wastes through shallow ground-water flow-paths into streams.



LOCATION MAP — PLANT VOGTLE/SRP

Figure 15

61. This experience at SRP has little applicability to Plant Vogtle for several reasons. First, there is no planned disposal of radioactive waste at Plant Vogtle. Consequently, there will be no continuous, planned release of contaminants as there was at SRP. Secondly, there are significant geologic differences between SRP and VEGP. Unlike the geology at VEGP, the geology of the A-Area at SRP does not preclude the possibility of contaminated ground-water percolating downward to the Cretaceous aquifer.

A. The Geology at SRP

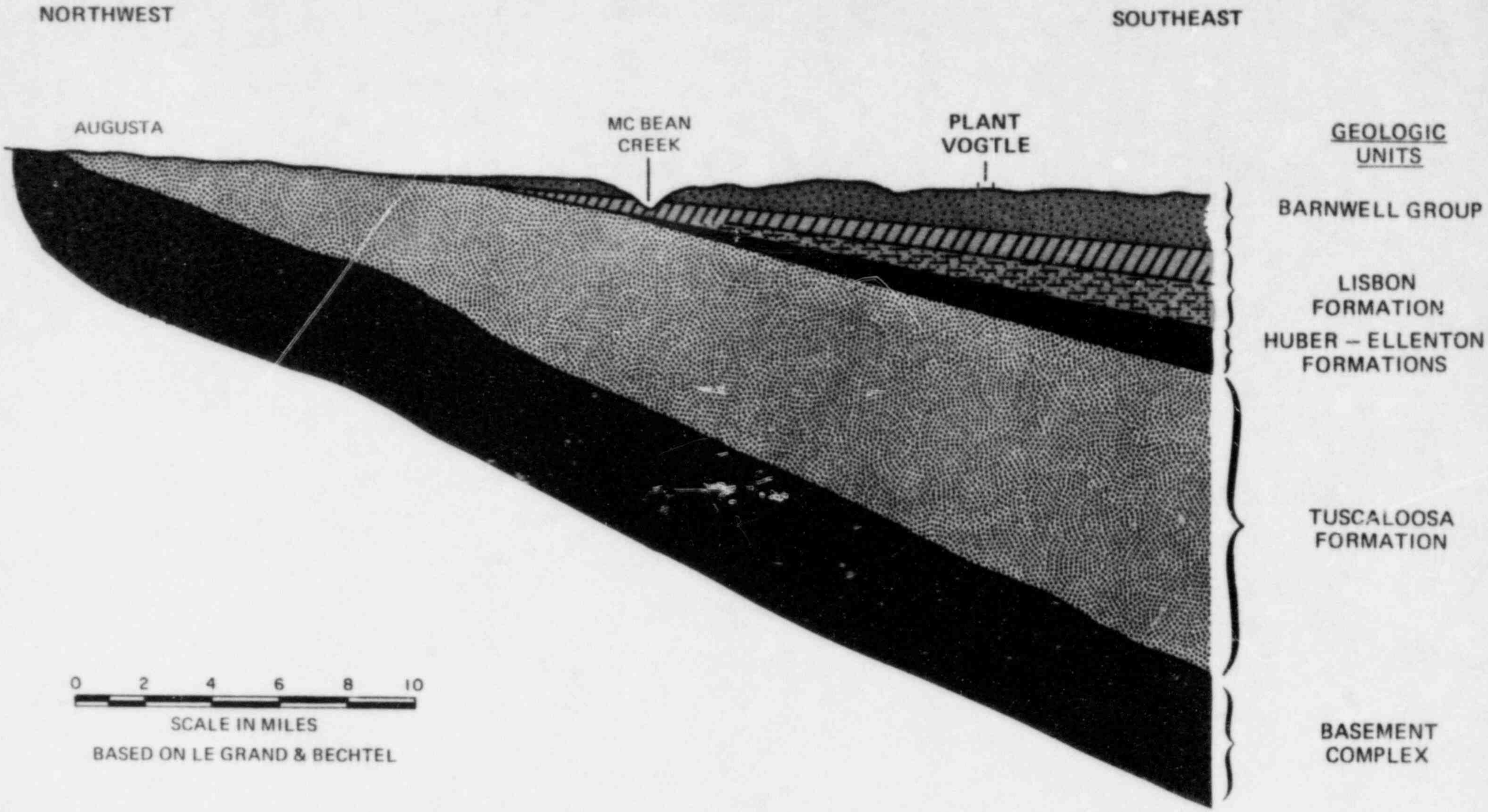
62. A significant consideration in comparing VEGP and SRP is that the same geologic formation has different physical characteristics from place to place as a result of changes in depositional environment (facies changes). The changes result in different types of sediments being deposited (limestone, sands, etc.) affecting the grain size, chemical composition, and other characteristics of the materials. Similarly, ground-water characteristics (i.e., permeability, porosity, and transmissivity) of the formations vary with these changes.

63. At SRP, the "green clay" unit is the lithologic equivalent of the Blue Bluff marl. SRP studies have assigned sandy marls, limestones, and interbedded sands above the "green clay" to the "McBean Formation." The lithologic character of the McBean Formation changes significantly over the area covered by the large SRP reservation (over 300 square miles). The

"green clay" also varies significantly in composition and thickness from place to place under the SRP. The Congaree Formation at SRP is the stratigraphic equivalent of the unnamed sands (lower member, Lisbon Formation) at VEGP. The Congaree Formation is comprised of sand and sandy clay.

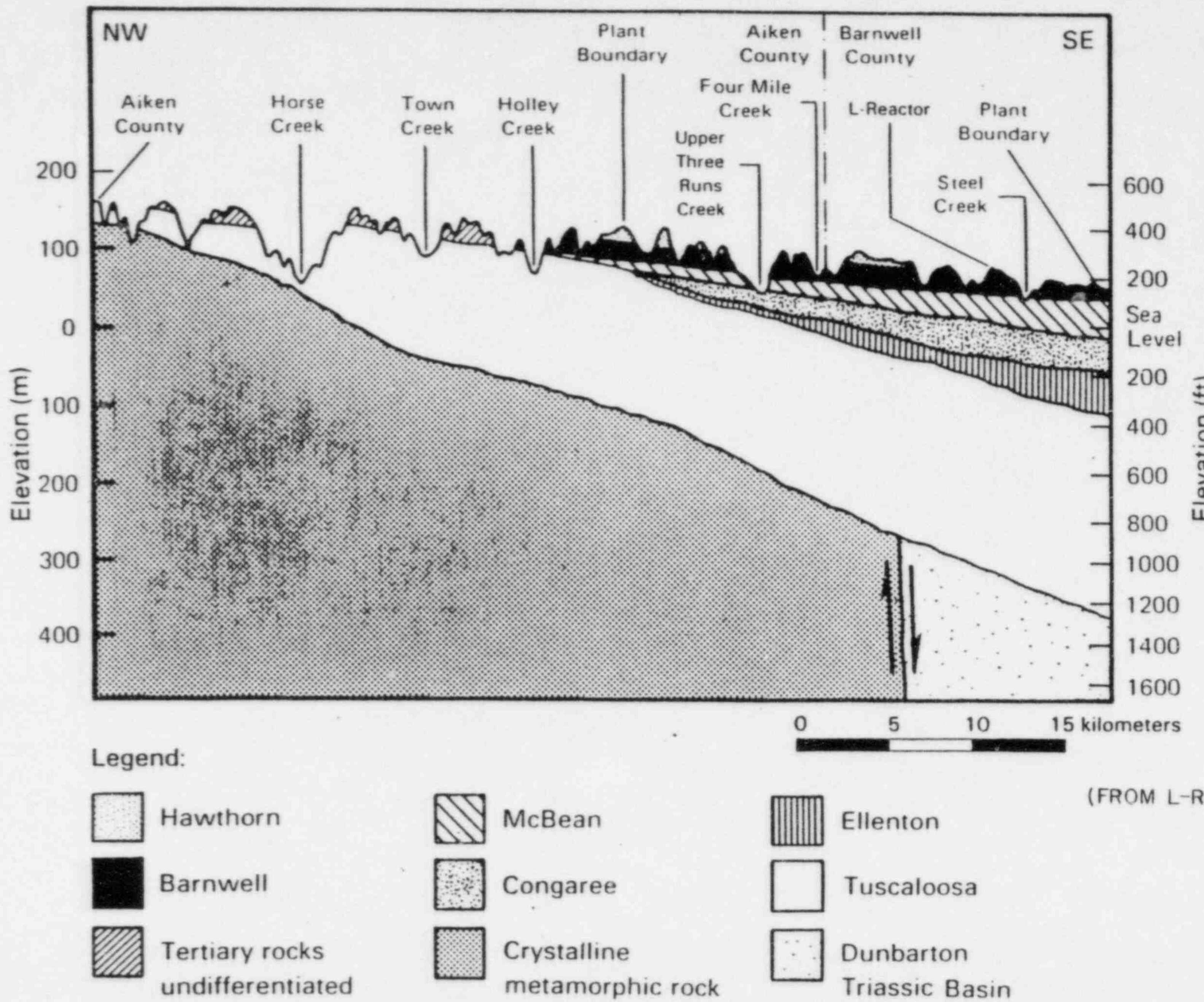
64. Because of the stratigraphic and lithologic differences, the hydrogeology at VEGP cannot be equated with the SRP as a whole. Figure 16 is a generalized section through Plant Vogtle site and Figure 17 is a section through the SRP. Any specific comparison must be made between Plant Vogtle and a particular area (i.e., M, A, H, L, etc.) of the SRP. A comparison with three such areas (H, A and M) is discussed in the following paragraphs.

65. H-Area, near the center of the SRP, is underlain by the "green clay" layer. As reported in U.S. Department of Energy, Final Environmental Impact Statement: Operation of the L Reactor (May 1984), "[t]he green clay layer at the top of the Congaree Formation appears to be continuous in the central SRP area. . . . To the south it appears that the green clay thickens to about 7 meters in L-Area and 18-meters in the southeastern portions of the SRP to become what is referred to in Georgia as the Blue Bluff marl of the Lisbon Formation." L-Reactor EIS, App. F at F-36. A section through H-Area is shown on Figure 18. The green clay forms an effective barrier to ground-water movement and is the confining layer above the Tertiary aquifer in H-Area. Although the hydrogeology of



REGIONAL GEOLOGIC SECTION
PLANT VOGTLE

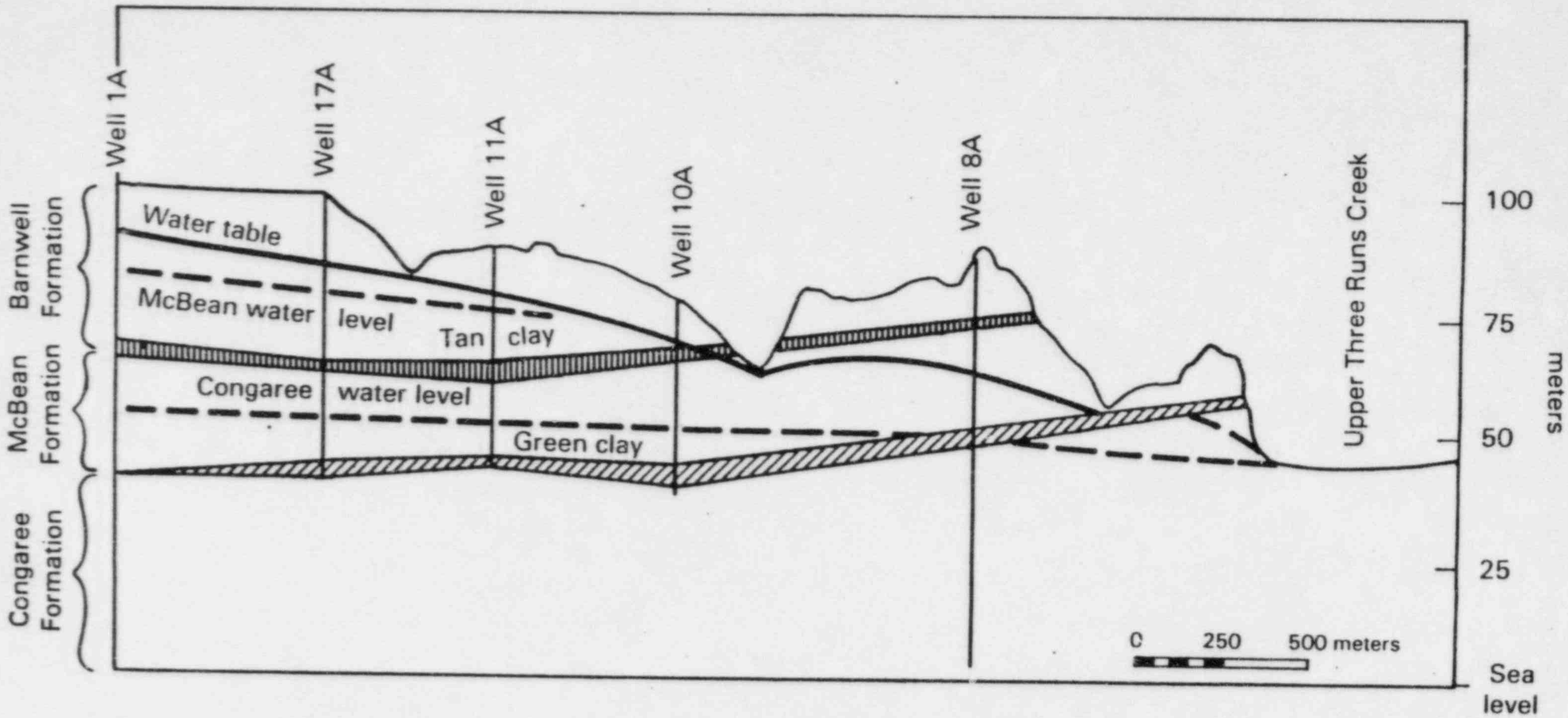
Figure 16



(FROM L-REACTOR EIS)

GEOLOGIC SECTION THROUGH SRP

Figure 17



(FROM L-REACTOR EIS)

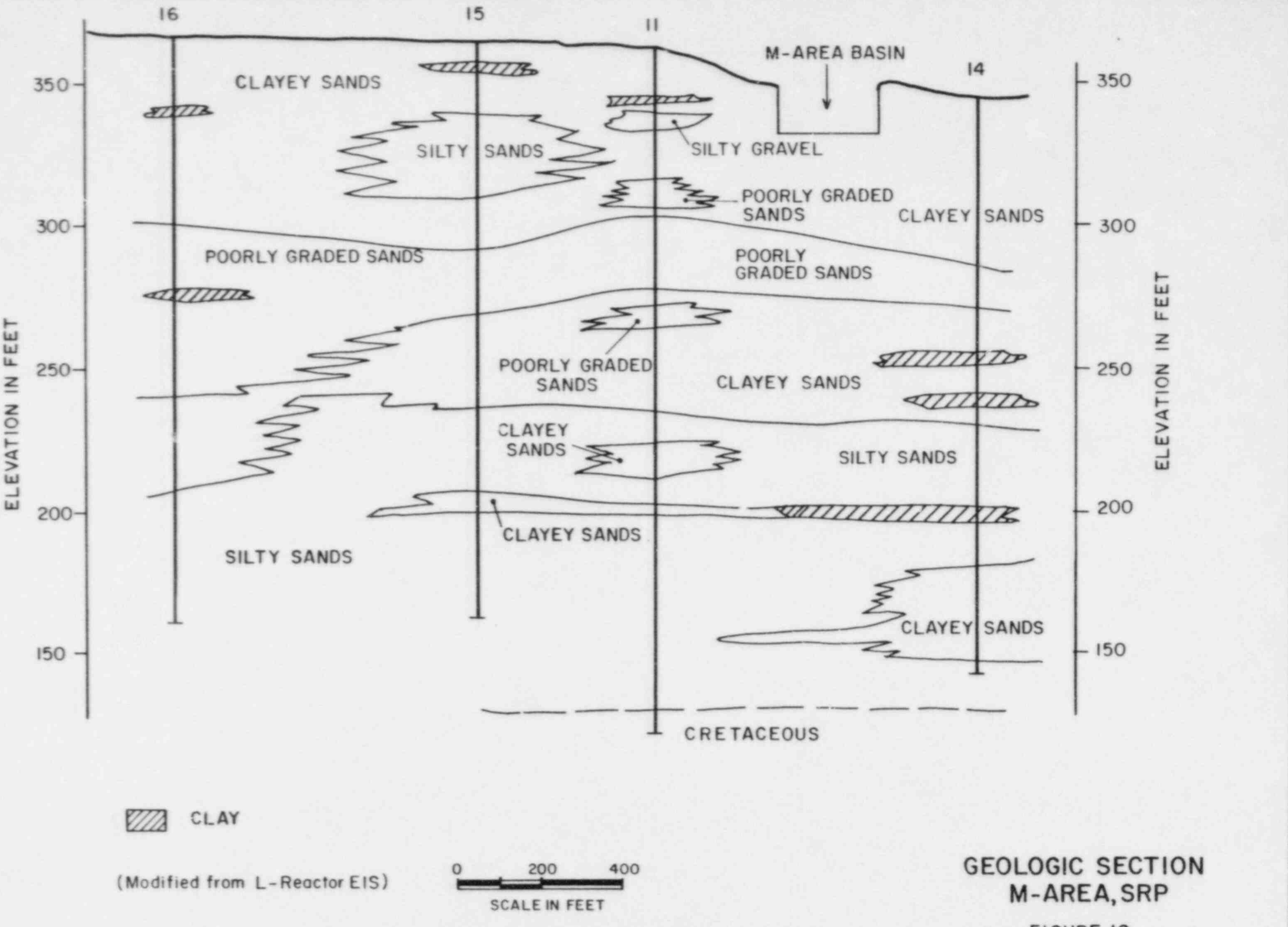
GEOLOGIC SECTION, H-AREA, SRP

Figure 18

H-Area is not precisely the same as at Plant Vogtle, it is similar.

66. M-Area (and the adjacent A-Area), located near the northwestern boundary of the SRP, is underlain by somewhat different geologic materials. Mainly, the green clay confining layer discussed above becomes thinner and discontinuous. L-Reactor EIS, App. F at F-36. There is thus little impedance to downward vertical flow within the Tertiary sediments. Id. at F-74. Figure 19 is a section through M-Area showing very little clay or any other relatively impermeable layer separating the Cretaceous aquifer from the water-table aquifer.

67. As is evident from the discussion above, the most significant difference between the subsurface geology at well 53A (where the contamination at SRP was detected) and that at the VEGP site is the absence of marl at well 53A. At SRP well 53A, the Ellenton Formation is the only confining layer above the Cretaceous aquifer. Pumping tests at Well 53A and a review of the driller's log indicate that the Cretaceous aquifer receives leakance from the overlying formations and that the overlying Ellenton Formation has low to moderate permeability. Therefore, there is hydraulic connection between the water-table and Cretaceous aquifers in the area at SRP where contamination of the Cretaceous aquifer was detected. The Cretaceous aquifer at SRP could have been contaminated by percolation from surface sources; the presence of the Blue Bluff marl precludes this possibility at VEGP.



(Modified from L-Reactor EIS)

GEOLOGIC SECTION
M-AREA, SRP

FIGURE 19

B. Wells as a Pathway for Contaminants

68. In the construction of both observation and production wells, a grout seal is normally placed in the annular space between the wall of the drilled hole and the casing. A cement bond log to test the presence and integrity of the grout seal in Well 53A indicated that most of the bond was marginal or bad. A study of the contamination of well 53A has hypothesized that contaminants might therefore have migrated from the Tertiary to the Cretaceous aquifer along the well annuli to the well screens. Geraghty & Miller, Inc., "Assessment of the Presence of Volatile Organic Compounds in Water-supply Well 53A, A-M Area, Savannah River Plant" (1983).

69. All of the holes that were drilled through the Blue Bluff marl and into the underlying confined aquifers at Plant Vogtle are listed on Table 1. The status of each hole is also shown. It is normal practice of the engineering firms conducting the drilling of exploratory holes to fill them with grout following their completion, unless they are utilized as an observation or production well. Table 1 includes 17 active wells. Nine are active ground-water observation wells open to the Tertiary aquifer. There are also four production wells open to the Tertiary aquifer, three of which supply construction water and one of which supplies water for the Simulator Building. In addition, four wells are completed as production wells open to the Cretaceous aquifer; three are plant operation make-up wells (only two of which are presently planned to be utilized), and the fourth is a test well.

TABLE 1

HOLES THAT PENETRATE BLUE BLUFF MARL AQUICLUDE

(Drilled into confined aquifer)

Hole Number	Status	Hole Number	Status
1	Grouted	107A	Grouted
2	Grouted	109	Grouted
3	Grouted	111	Grouted
5	Grouted	111A	Grouted
6	Grouted	113	Grouted
7	Grouted	114	Grouted
8	Grouted	114A	Grouted
9	Grouted	116	Grouted
10	Grouted	119	Grouted
11	Grouted	122	Grouted
12	Grouted	132	Grouted
13	Grouted	133	Grouted
14	Grouted	134	Grouted
15	Grouted	135	Obs. well, grouted
16	Grouted	136	Grouted
17	Grouted	137	Grouted
18	Grouted	138A	Grouted in marl**
19	Grouted	139	Grouted
20	Grouted	144	Obs. well, grouted
21	Grouted	144A	Grouted
22	Grouted	145	Grouted
23	Grouted	147	Obs. well, grouted
24	Obs. well, grouted*	152	Grouted
25	Grouted	156	Grouted
26	Obs. well, grouted	157	Grouted 1
27	Obs. well, active	170	Grouted
29	Obs. well, active	175	Obs. well, grouted
31	Obs. well, grouted	180	Grouted
32	Obs. well, grouted	181	Obs. well, grouted
33	Obs. well, grouted	182	Grouted
37	Grouted	202	Grouted
38	Grouted	203	Grouted in marl
39	Grouted	204	Grouted in marl
40	Grouted	216	Grouted
42	Grouted	217	Grouted
42A	Obs. well, grouted	218	Grouted
42B	Obs. well, grouted	219	Grouted
42C	Obs. well, grouted	220	Grouted in marl
45	Grouted	221	Grouted
101A	Obs. well, grouted	222	Grouted
102	Grouted	223	Grouted
102A	Grouted	224	Grouted
104A	Grouted	225	Grouted
105	Grouted	226	Grouted
106	Grouted	227	Grouted
107	Grouted	228	Grouted

(0632g)

TABLE 1

HOLES THAT PENETRATE BLUE BLUFF MARL AQUICLUDE

(Drilled into confined aquifer)

Hole Number	Status	Hole Number	Status
229	Grouted	502	Grouted
230	Grouted	503	Grouted
235	Grouted	503A	Grouted
236	No closure record	504	Grouted
237	No closure record	505	Grouted
238	Grouted in marl	506	Grouted
239	No closure record	507	Grouted
243	Obs. well, grouted	508	Grouted
244	Obs. well, grouted in marl***	509	Grouted
245	Obs. well, grouted	510	Grouted
246	Obs. well, grouted	511	Grouted
247	Obs. well, grouted in marl	512	Grouted
248	Obs. well, grouted in marl	513	Grouted
249	Obs. well, grouted in marl	514	Grouted
301	Grouted	515	Grouted
302	Grouted	516	Grouted
303	Grouted	517	Grouted
304	Grouted	518	Grouted
305	Grouted	519	Grouted
306	Grouted	520	Grouted
307	Grouted	521	Grouted
308	Grouted	522	Grouted
309	Grouted	523	Grouted
310	Grouted	524	Grouted
311	Grouted	601	Grouted
312	Grouted	603	Grouted
313	Grouted	605	Grouted
314	Grouted	607	Grouted
316	Grouted	609	Grouted
319	Grouted	609A	Grouted
322	Grouted	610	Grouted
324	Grouted	611	Grouted
326	Grouted	613	Grouted
329	Grouted	615	Grouted
331	Grouted	617	Grouted
333	Grouted	619	Grouted
334	Grouted	621	Grouted
335	Grouted	623	Grouted
336	Grouted	624	Grouted
337	Grouted	625	Grouted
338	Grouted	627	Grouted
339	Grouted	629	Grouted
408	Grouted	631	Grouted
409	Grouted	633	Grouted
501	Grouted	702	Grouted
501A	Grouted	704	Grouted

TABLE 1

HOLES THAT PENETRATE BLUE BLUFF MARL AQUICLUDE

(Drilled into confined aquifer)

Hole Number	Status	Hole Number	Status
705	Grouted	P-5	Grouted
705A	Grouted	RF-1	Grouted
706A	Grouted	RF-1	Grouted
707	Grouted	RF-2	Grouted
709	Grouted	RF-3	Grouted
711	Grouted	RF-4	Grouted
712A	Grouted	RF-5	Grouted
713	Grouted	RF-6	Grouted
850	Grouted	RF-7	Grouted
850A	Obs. well, active	RF-8	Grouted
851	Grouted	RF-9	Grouted
851A	Obs. well, active	CW-1	Construction well, active
852	Obs. well, active	CW-2	Construction well, active
853	Obs. well, active	CW-3	Construction well, active
854	Obs. well, active	MU-1	Make-up well, active
855	Obs. well, active	MU-1A	Make-up well, grouted
856	Obs. well, active	MU-2	Make-up well, active
P-1	Grouted	MU-2A	Make-up well, active
P-2	Grouted	SB-1	Simulator bldg. well, active
P-3	Grouted		
P-4	Grouted	TW-1	Test well, active

* Obs. well, grouted - hole was completed as observation well. Observation well was grouted at later date.

** Grouted in marl - hole was drilled through marl. Marl was grouted before hole abandoned.

*** Obs. well, grouted in marl - hole was drilled through marl. Marl was grouted and hole completed as observation well open to unconfined aquifer.

70. All observation wells monitoring the Tertiary aquifer, all make-up wells, the test well, and the production well at the Simulator Building, were sealed in the Blue Bluff marl with cement grout during well construction to prevent communication between aquifers. Applicants plan to abandon and grout the three construction-water wells upon completion of plant construction.

71. All of the remaining holes on Table 1 were for exploratory purposes only. There is documentation that all of the holes were grouted except 236, 237, and 239. Although there are no data to indicate the exact disposition of these holes, it is believed these were also grouted. These three holes are northeast of the power block, adjacent to the Savannah River. Ground-water in the water-table aquifer at the power block does not flow in this direction. Moreover, all three holes are in an area beyond the lateral extent of the water-table aquifer. Consequently, ground-water in the water-table aquifer could not reach these holes.

72. The grouting method used for sealing all exploratory holes, observation wells, make-up wells, the test well, and the production well at the simulator building, is the same. The method employed is commonly known as the "tremie method", which is performed by insertion of a small diameter pipe to near the bottom of the hole and pumping cement slurry through the pipe, filling the hole from the bottom up. Grouting continues until grout appears at the top of the hole. This method is employed

assure that the hole is completely grouted and no voids are present. Use of this method has ensured the integrity of the marl as a barrier to contamination.

Thomas W. Crosby

Clifford Farrell

Lewis R. West

Subscribed and sworn to before me
this 8th day of July, 1985.

Notary Public

My commission expires: APRIL 26, 1989.

OFFICIAL SEAL
MAVIS M. LYNDE
NOTARY PUBLIC – CALIFORNIA
San Francisco County
My Commission Expires April 26, 1989

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EXHIBIT A

PROFESSIONAL QUALIFICATIONS

Thomas W. Crosby

My name is Thomas W. Crosby. I graduated from Oregon State University with a Bachelor of Science degree in Geology in June 1973. For the past twelve years I have been employed by Bechtel as an engineering geologist. My responsibilities have been the field and office studies for the siting, design, and construction of major engineering projects, including nuclear power plants, hazardous waste facilities, dams, and tunnels.

I have been responsible for field exploration, data interpretation, report preparation, and regulatory review on nuclear power sites in Georgia, Pennsylvania, Washington, California, and Taiwan. My ground water experience includes supervision of monitoring well construction and testing at hazardous waste sites in New York, Tennessee, and Arizona. I have also supervised the installation and testing of large capacity production wells in Senegal, West Africa and Washington State.

I am a Registered Geologist and a Certified Engineering Geologist in the State of California, and a Licensed Geologist in the State of Oregon.

EXHIBIT B

PROFESSIONAL QUALIFICATIONS

Clifford R. Farrell

My name is Clifford R. Farrell. I have received a Bachelor of Science degree in geology from the University of Southern California in 1954, and have completed some graduate studies.

I have 31 years of experience in field and office studies in hydrogeology and engineering geology including investigations for the development of regional and local water supplies; design and construction of water wells; hydrogeologic studies concerned with the safety analysis of nuclear power plants and geologic studies for the planning and design of dams, tunnels, and power plants.

I worked for the California Department of Water Resources for 11 years. Initially I worked on alternative route studies for the California Aqueduct, becoming head of a unit responsible for geologic studies of tunnels, dams, and power plants. In 1961, I became head of a ground water and hydrology special studies unit that conducted basin-wide water supply studies.

From 1967 to 1969, before joining Bechtel, I completed an assignment with the U.N. Food and Agricultural Organization for the Huaura River Project in Peru. I was responsible for the proposed ground water development plans and for geologic investigations of dam sites.

For the past 16 years I have been responsible for the technical direction of ground water investigations conducted by the Bechtel Engineering Geology Group. I have directed geologic and ground water studies concerned with the safety analysis of eleven nuclear power plant sites and with the design and characterization of hazardous, non-hazardous, and low-level waste repositories. Characterization studies have included contaminant plume identification and radionuclide migration studies. Other studies have included: design and construction of ground water supplies for mining, industrial, and agricultural developments in many countries, including Canada, Saudi Arabia, Australia, Indonesia, Algeria, and Senegal; seepage and pollution analysis of storage ponds at several U.S. power plant sites; and environmental impact studies. I have designed dewatering and ground water control systems for power plant foundations, open-pit mining, and other projects.

I am a registered geologist and a certified engineering geologist in the State of California.

EXHIBIT C

PROFESSIONAL QUALIFICATIONS

Lewis R. West

My name is Lewis R. West. I have a B.S. degree in Geology from the University of Southern Mississippi and some graduate studies in geology at University of Nevada, Las Vegas.

I was employed by the Ground Water Branch of the U.S. Geological Survey for seven years. During this period, I worked in Alabama for four years and at the U.S.A.E.C. Nevada Test Site for three years.

From 1964 to 1973, I was employed by Environmental Research Corporation in Las Vegas, Nevada as field geologist and field office manager. I was responsible for the liaison between the home office in Virginia and the AEC's Nevada Operations Office. My duties involved investigations of tunnels and drill holes for input to determine containment and ground motion effects in relation to atomic bomb testing.

For the past 12-1/2 years, I have been employed by Bechtel as a Hydrogeologist. My responsibilities include all aspects of ground water occurrence and interaction in respect to foundation, dam sites, retention ponds and engineering geology design criteria as well as development of industrial ground water supply systems.

I am a Registered Geologist in the State of California.